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THE GEOLOGY OF THE NORTHEAST COAST OF LABRADOR.

By Reginald A. Daly.

With Thirteen Plates.

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No. 5.—*The Geology of the Northeast Coast of Labrador.*
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(*Bearings refer to the true Meridian.*)

Introduction.

In the late summer of 1899, Mr. Huntingdon Adams, of the class of 1901 at Harvard, paid a flying visit to the coast of northern Labrador. He was so impressed with the beauty of the fiords and mountains of the country that he conceived the idea of organizing a party which should spend the following season exploring in the same region, with intent to bring back more definite information regarding its general geography than had yet been obtained. With the advice and aid of Prof. E. B.

Delabarre of Brown University, the scheme was successfully carried out, and a most profitable and enjoyable summer spent by those who participated in the expedition. The party also included Messrs. H. B. Bigelow, L. B. McCormick, and H. W. Palmer, undergraduates of Harvard. I was asked to accompany them and record any geological observations that might be possible on a trip of the kind proposed. Rather more was accomplished in this direction than was hoped for at the outset, and the results are believed to be of sufficient interest to warrant some degree of detail in their recital. The following pages are intended to afford a brief treatment of the more important problems met with during the summer; some of these have found solution, others will, it is hoped, be more clearly defined for future visitors to a little known shore.

The equipment of the expedition was quite modest but sufficed for most needs, excepting that for rapidity of travel. The vessel selected for the journey was the "Brave," a forty-ton fishing schooner, just rebuilt and specially fitted up to be the summer home of the party and of the four seamen employed to take the larger share of the navigation required. Thoroughly staunch and clean, and commanded by a skipper of unusually wide experience and close knowledge of the thousand dangers of this coast, the craft was found to be both safe and comfortable. The instrumental outfit included five aneroid barometers; two ordinary thermometers; a corrected thermometer lent by the Superintendent of the United States Coast Survey, from whom there were also obtained two sets of salinometers and a hydrometer cup; four Negretti-Zambra deep-sea thermometers, and five hundred fathoms of piano-wire, lent by Mr. Alexander Agassiz; a sextant, lent by Brown University; and a prismatic compass. The tools in trade of a botanist, an ornithologist, and a geologist, were likewise represented on board. Professor Delabarre worked assiduously on the flowering plants encountered on the route, and collected freely from the cryptogamic vegetation which is so striking a feature of the coast. Mr. Bigelow's former experience enabled him to seize quickly the peculiar ornithological features of the coast, and he has added several species new to its list of birds.[1] The writer, though chiefly occupied with the general geology ashore, spent some time in a limited study of the hydrography of the Labrador Current. Before proceeding to the discussion of results, it will be well to give a brief account of the itinerary. By so doing, the conditions under which the observations were carried on may be most easily understood.

[1] Cf. Auk, 1902, xxvii. pp. 24–31.

Itinerary of the Cruise.

On June 25th the "Brave" weighed anchor at St. John's, Newfoundland, and sped rapidly northward with a fair wind to about Lat. 49° 20′ north. The next day a strengthening gale decided our captain to run for shelter at Greenspond. Compelled to remain there until July 2d, we had leisure to examine the hummocky islands of Laurentian porphyritic granite and to study the hard conditions of life in a town of Newfoundland fisher-folk. We came to a full understanding of the fact that the dangerous sea more readily gives them livelihood than the soilless ledges which need imported earth before they yield a useful vegetable. A quick run without incident, save a halt at Change Island, brought us to Cape Bauld at noon on July 4th. Here we were destined to disappointment in the hope that the Straits of Belle Isle might be crossed and "the Labrador" attained without delay. The northern half of the strait was found to be impassable on account of a broad stream of pan-ice; the "Brave" beat back and anchored at nightfall in Kirpon Harbor which lies in the "tickle" east of Kirpon Island.

The next day, from a hill north of the harbor, we had a remarkably striking view of drift-ice streaming west-southwest into the strait and southward past Belle Isle along the east coast of Newfoundland. The Labrador current was a vivid reality to us as we watched the truly majestic procession of these dazzling migrants from a polar sea. That day closed with no indication that our snug harbor would be threatened with an invasion, but we came on deck the next morning to find ourselves in an Arctic landscape. The schooner was firmly wedged in among the heavy pans of ice which during the night had quietly drifted into the "tickle" under the impulse of north wind and flood current. The unusual thickness and quantity of the ice, coupled with the steady character of the north or "up" wind, caused our detention in this harbor until the morning of the 13th. These seven days were spent among the picturesque hills and valleys in the vicinity and among the exquisitely tinted ice-floes. Among the sedimentary rocks which compose Kirpon Island, Jacques Cartier Island, and the mainland roundabout, an interesting boulder basalt, with pillow structure, was discovered. It is hoped that a description of this typical occurrence will be given on another occasion.

Along with more than a hundred other schooners from the many anchorages of this indented coast, the passage of the straits was finally made. Not the least memorable scene of the summer was this brilliantly sunlit expanse of water covered with the great fleet and with a long train of icebergs, two of which were probably the loftiest seen during the cruise.

Headed by the wind, immersed in thick fog, and trapped once more by ice-floes, we lay at anchor in Assizes Harbor on the north side of the straits until the 17th, when we escaped again and ran sixty-five miles to Seal Island. Three days' delay by ice and head winds here, and three more at West Bay Head on the south side of Hamilton Inlet, completed the first month of the cruise and evoked many remarks from our skipper on the extraordinary difficulty of "getting down" the coast this season. The failure of westerly and southerly winds and the massive character of the drift-ice so late in the summer were alike unparalleled in his thirty years' experience on this coast.

"The extraordinary smoothness of the sea covered by drift-ice, even when the pans are widely spaced, is truly astonishing to one making his first voyage in such waters. His sailing ship may be favored with a fresh breeze and yet the ocean surface be quite level, save for the minute rippling characteristic of a small pond ruffled by a summer breeze; ground-swell does not exist. It is a matter of common knowledge among the fishermen of the Atlantic Labrador coast that the Labrador current, or 'tide,' as they invariably express it, often shows high velocity, although its surface, for a length of a thousand miles and a breadth variable but at times as much as three hundred miles, is covered with loose pan-ice. At such times, the wind is, or has just been, strong and from a northerly quarter. We are justified in believing that the pans act as the sails which, in ice-free waters, are represented by wind-waves. Floes and pans project above the surface from one to twenty feet or more. They may be expected to exert a coercive force on the film of relatively fresh water derived from the melting of the ice in contact with the heavier salt water beneath. According with the behavior of such 'dead water,' as described by Nansen and others, the light surface layer will tend to move *en masse* and in the direction of common pull exercised by the wind-driven masses of ice. By reason of friction the motion will be communicated to lower layers of the sea. This cause of surface currents is of importance to the theory of movement of those polar waters which, for several months after the winter ice begins to break up, are free from larger wind-waves. Deprived of its chief sails, the Labrador current, always sensitive to wind conditions and at times subject to temporary reversal with contrary winds, yet preserves and perhaps exceeds during the period of ice-drift, the average velocity of current-flow for the year."[1]

On the 24th, the mouth of Hamilton Inlet was crossed. Ice afforded little trouble henceforth, but head winds prevailed; so that, at frequent

[1] Science, Nov., 1900, vol. 12, p. 688.

intervals, we were compelled to drop anchor and wait for the short-lived favorable winds on which our progress against the south-flowing current depended. The longest run made between the straits and Hebron, a distance of eight hundred miles, was only fifty-three miles in length. Twenty-two halts of greater or less duration were made on this part of the journey. Nachvak Bay, eleven hundred miles from St. John's, and the objective point of the expedition, was not reached until August 21st. Thus but a small portion of the summer remained for the exploration of the high mountains in the north. At the end of two weeks we were forced to weigh anchor and begin our homeward journey.

Disappointing as our rate of progress was in this one respect, there yet remained the advantage that, with so many opportunities to land in southern Labrador, we were able to sample, with fair continuity, the geology of a coast-line which is in every part in need of investigation. In fact, some of the most interesting problems of the summer would have been necessarily left untouched, if our early ambition to make a rapid northward run had been satisfied. The return to St. John's was accomplished in four weeks, during which time, several gaps in the required series of observations were filled up. We dropped anchor for the last time in the early morning of Oct. 3d, having been out a few hours less than a hundred days. In that period, we had been thirty-nine days at anchor against our will, but there was, at each detention, always the consolation of an opportunity to get a view, however hurried, of a region full of novelty and at times no less interesting than the goal of our endeavor, the Torngats of the north. At the same time, it is clear that nothing more than a reconnaissance could be made at any of the anchorages.

Observations on Topography and Bed-rock Geology.

The general form and composition of the old-mountain plateau of Labrador have already been admirably treated by Packard,[1] Bell, and Low, and by the writer of the article "Labrador" in the Encyclopædia Britannica. These and earlier writers agree that the northeastern coast of the peninsula marks the edge of the great Archæan shield of North America; and, further, that, if exception be made of the "Domino quartzite," the Ramah slates, and certain occurrences of sedimentary rocks in Nachvak Bay, the bed-rock of the coastal belt is throughout

[1] A bibliography relating to works on Labrador is published in "The Labrador Coast" by A. S. Packard, Jr. New York and London, 1891.

crystalline. Gneisses, intrusive granites, syenites, gabbros, and traps prevail from the Straits to Cape Chidley.

The results of last summer confirm this general view, but it was found that sedimentary formations not heretofore described appear in great development on the shield border. At Pomiadluk Point, at Aillik Bay and in the Mugford region, as well as in the long stretch from Saeglek Bay to Ramah, the crystallines form the foundation to stratified series of very diverse character. These merit particular notice in a sketch, however brief, of the general geology of the coast. The extrusive lavas of the Mugford series, the intrusive traps which occur in astonishing profusion in the 700-mile belt, and the gabbros of Paul's Island and vicinity will also claim attention. It will be shown that a correlation of the strike-directions of schists and sediments indicate in the coastal border a decided N.W.–S.E. trend which corresponds rather closely with the average trend of the shore-line. Finally such observations as have been made on the topography and physiography will be described in connection with the bed-rock geology.

From the Straits of Belle Isle to Paul's Island.

General Topography. — As far north as Cape Mugford, over five hundred miles from the Straits, the edge of the plateau is in plan extremely ragged. Numerous fiords, ria-like bays and a vast archipelago of outlying islands or skerries form a coastal fringe. The similarity of landscape is so great that Forbes's description of the coast of Norway on the route from Trondhjem to Bergen may be repeated for this portion of Labrador. A series of inlets penetrates "in all directions a low, bare, rocky land, partly island, partly continent, nowhere rising but to a very small height above the sea, and so monotonous in character, and destitute of long reaches, or natural landmarks, as to seem to require an almost superhuman instinct for its pilotage."[1]

The contours of the islands are repeated in the hills of the low plateau of the mainland; the inlets, sounds, and narrow channels among the islands (the "tickles" of the fishermen) represent the submerged equivalents of the valleys on the mainland. From any commanding hill on island or mainland, the eye ranges far and wide over a surface showing everywhere the evidence of universal and profound glaciation. Unobscured by forest, soil, or thick drift, and singularly expanded because of the crystalline clearness of the atmosphere, the view

[1] J. D. Forbes, Norway and its Glaciers, Edinburgh, 1853, p. 104.

typifies that which may be had in the Laurentian Highlands of Canada or in the Archæan of the Scottish Highlands. It is a great wilderness of innumerable rounded, ice-worn hummocks generally gneissic in composition. Among the *roches moutonnées* lie equally countless ponds and bogs connected by the small streams of a most disordered drainage.

In sheltered places and at the higher altitudes the snow lies throughout the year. On Pomiadluk Point, two ravines, running from about the four hundred-foot contour to the eight hundred-foot, a distance of four hundred yards in each case, were found to be occupied with snow to a depth of from fifty to seventy-five feet. Typical transverse crevasses ten to twenty feet in depth and yawning widely at their mouths indicated by their attitude and down-stream curvature that the snow was moving, glacier-like, down the slope. No blue ice was seen, but it is possible that such existed in the deeper parts. Though many such banks were found on the coast, especially on the higher mountains of the north, none of them so closely approximated a true glacier in look as these on Pomiadluk Point.

The existence of the coastal fringe suggests at once that the plateau has been drowned by recent subsidence. Yet, in view of the evidence derived from the study of hanging valleys and fiords in Norway, Alaska, and elsewhere, it is open to question whether the same glacial erosion which has so conspicuously moulded the mainland may not be as well responsible for the depressions on the plateau-border now occupied by salt-water. In other words, the differential erosion of an ice-sheet extending out beyond the island-zone may have excavated these depressions which would permit of the entrance of the sea when the ice had left the country. It is significant that where, on this coast, north of Hebron, glacial erosion was confined to the main valleys, the fiords corresponding to the latter are magnificently developed but the islands largely fail. The sounds and tickles do not now present the systematic relations of drowned river-valleys; such irregularity as is known to characterize the erosive activity of valley glaciers is without doubt represented beneath an ice-cap and might leave just such channels below sealevel as a memorial of that fact. It cannot yet be asserted that differential glacial erosion has contributed more to the present outline of the Labrador coast than simple drowning, but it has certainly affected the original preglacial form of the plateau to a great extent. In any case, it is important to recognize in a systematic discussion of shore-lines, a type wherein glacial erosion, independently of crustal movement, may produce an island-zone similar to that of a "drowned coast."

While this glaciation has given a monotonous though not unpleasing character to the plateau, the headlands and islands of the coast exhibit in detail a great variety of form. Sea-cliffs, benches, sea-chasms, fretted ledges, beaches, gravel-bars, spits, and narrow coastal plains, all belonging to the zone of postglacial emergence, add much to the scenic quality and interest of a voyage along the coast. In this rugged soilless belt, it is literally true that he who runs may read, and if he be a student of geological processes, will find perpetual instruction from the coastal views.

The Geology. — South of Hamilton Inlet, the bed-rock seems to belong entirely to the crystalline complex (Plate **11**). Assizes Island and the mainland at the mouth of the St. Charles River, are underlain by greatly contorted biotite and hornblende gneisses, biotite schists and amphibolites; quartz and pegmatite veins occur in large numbers. Similar rocks were found at St. Francis Harbor on Granby Island. The geology is further much complicated by the frequent occurrence of large areas of massive and gneissoid granites and diorites and by an equally persistent appearance of trap-dikes. The coarse gneissoid granite of Great Caribou Island on the south side of St. Lewis Sound, was remarked for its development of ilmenite in anhedrons from one eighth to one half an inch in diameter. The mineral showed a perfect development of the octahedral parting which was again seen in the ilmenite crystals an inch in diameter that are plentifully distributed in a vein of graphic granite at Rogue's Roost, Seal Island. This vein is twelve feet in average width and is beautifully exposed for some three hundred feet of length. Seal Island is chiefly composed of coarse hornblende granite cutting coarse diorite and is itself cut by pegmatites, fine-grained aplites and numerous wide dikes of hornblende biotite diorite.

Drift-ice prevented our anchoring in Domino Harbor and thus I had no opportunity of seeing in its classic locality the "Domino Gneiss" of Lieber,[1] nor the quartzitic rock described by Packard[2] and interpreted by Bell[3] as representing a remnant of the Huronian in eastern Labrador. In a private communication to the writer, Packard states that he is inclined to agree with Bell that the latter rock is in reality an arkose. At Pottle's Cove, West Bay, which Packard's map places in the zone of the Domino Gneiss, a peculiar and striking rock-type has large development. It is a medium-grained to fine-grained gneiss weathering under

[1] O. M. Lieber, Rep. U. S. Coast and Geodetic Survey, 1860, p. 402.
[2] A. S. Packard, Jr., The Labrador Coast, 1891, p. 286.
[3] R. Bell, Scot. Geog. Mag. 1895, Vol. XI., p. 349.

the almost universal covering of peat, to a grayish-white color highly suggestive of weathered quartzite. The structure is linear-parallel and is formed with extraordinary perfection. The gneiss is penetrated by dikes and more irregular intrusions of diorite which are probably related as to age and origin with the trappean mass of Tub Island.

Nowhere on this coast are trap-dikes so massive or so influential in determining the topographic form of the country, as in the region about Ice Tickle on the north side of Hamilton Inlet. Rodney Mundy Island and Ice Tickle Island are each about three parts composed of medium to coarse grained hornblende granitite, granitoid gneiss and fine-grained gneisses. The remaining surface is occupied by a multitude of great dikes, thick sheets, pods, or stock-like bodies of diabase which, on account of their black color, contrast very strongly with the other crystallines round about. The trap wherever examined is plainly intrusive. No vesicular structure was to be found. Both contacts of a typical pod showed the chilled and porphyritic zone characteristic of intrusion. A fine example of the dikes is seen on the ridge at Indian Harbor. It has parallel walls, is some two hundred feet in width, and is visible as a steep black wall a quarter of a mile along the Tickle. Very commonly the dikes are seen to swell out into thick trap-bodies three hundred to one thousand feet in diameter, and again, a stock will project through the gneisses without visible connection with the trap of the neighboring hills. The average strike of the intrusive masses is N. E.–S. W. The trap forms all the higher elevations, which thus assume the varying outlines of palisade, ridge, or dome, according to the shape of the intruded rock-body. Between them the schists and granites, on account of their inferior power to resist erosion, now underlie valleys that open seaward on the deep bays and tickles of a "drowned" coast-line. One will go far to discover so fine an example among wholly crystalline rocks, of such control over land-forms — the control of differential resistance to weathering.

The same association of gneiss-valleys and trap-hills extends at least ten miles to the westward of Ice Tickle. At Sloop Harbor, though still plentiful, the dikes (here hornblende biotite diorite with accessory augite) are too narrow to produce a great effect on the topography. Webeck Island, a soilless, driftless, because wave-swept, granitic swell a half-mile or more in length, affords a splendid exhibition of twenty-two huge dikes cutting across the island in parallel fashion. On the mainland, opposite Jigger Island near Webeck Island, an interesting group of dikes in granitite was studied. One of these is a handsome biotite diorite porphyrite; the other, a slightly porphyritic alkaline rock, with phenocrysts of microcline and a groundmass composed of microcline and quartz in micropegmatitic intergrowth and an amphibole with the characters of riebeckite.

Massive granitic rocks were found at each anchorage between Hamilton Inlet and Hopedale. At Sloop Harbor the hills are composed chiefly of a coarse hornblende granite; Jigger Island exhibits granitites similar to that of the mainland; thirty miles farther north, on the mainland opposite Conical Island, a flow-breccia of granitite cutting diorite proved to be extensive. Associated with similar rocks are the only sedimentary formations that were seen to the southward of Hopedale.

Sedimentary rocks at Pomiadluk Point. — Pomiadluk Point forms the extremity of a bold peninsula which projects northeastwardly from the mainland in about 55° N. Lat. Stretching along the southeast side of the peninsula for a distance of some five miles, is a broad bench from two to three hundred feet in height and from one and a half to two miles in breadth. On the southeast the bench falls into the sea quite abruptly; on the northwest it ceases at the foot of a steep ridge of granitite that composes the main part of the peninsula. Barometric readings on two different days accorded well in giving eleven hundred feet as the elevation of a prominent summit of the ridge. Its average height is not less than one thousand feet; toward Cape Strawberry it rises to twelve hundred feet, and is thus the highest land encountered on the coast between the Cape and the straits of Belle Isle.

The glaciated ledges of the flat though hummocky bench have been wave-swept during postglacial submergence and thus one can study the rock-composition and structure with exceptional ease. The bench is conterminous with a well exposed mass of metamorphic conglomerate. Along four cross-sections about a half a mile apart, the sedimentary band was proved to be very homogeneous. In a silicious matrix, often highly schistose, pebbles and boulders up to one or more feet in diameter are embedded. They are composed of granitite, quartzite, vein quartz, granite porphyry and metamorphic sandstone. They are almost always considerably flattened, though the granitite pebbles have oftentimes so far resisted the shear as to present still well-rounded outlines. The schistose structure strikes steadily N. 15° W.; its dip is variable but steep and generally to the westward. Not allowing for duplication, the thickness of exposed conglomerate measured on this secondary structure-plane was estimated at eight thousand feet. On the west the conglomerate becomes finer-grained and for a distance of three hundred feet from the granitite contact, is replaced by a band of metamorphic sandstone. The structural features are here identical with those of the conglomerate. Part of the cement of both rocks is made up of epidote, which colors the rock an intense green, especially marked where myriads of epidote crystals have formed along the joint-planes.

The limited time at our disposal, the extensive covering of elevated beach deposits and of land-wash at the inner edge of the bench, and, in an important degree, the disturbing influence of clouds of mosquitoes, prevented the discovery of the actual contact between sandstones and granitite. The granitite-pebbles in the conglomerate are very similar in character to the rock of the great ridge and suggest that they were derived from it. The deformation of the conglomerate is represented in the granitite by the appearance, especially near the contact, of a schistose structure, with a trend common to that of the conglomerate; the two rocks have evidently been squeezed together.

A sharp lookout was kept for fossiliferous bands, but no organic remains were discovered. Thus no conclusion could be made as to the age of the sediments. They have a close superficial resemblance to the Archæan metamorphic conglomerate series of Finland which the writer had already seen in the field. These Labrador sediments are cut by diorite, granite porphyry and diabase dikes and by many pegmatite and quartz veins.

Sedimentary rocks in Aillik Bay. — Aillik Bay opens at a point about fifteen miles northwest of Pomiadluk Point. It is a picturesque inlet some five miles in length and three-quarters of a mile in width. Its axis is directed north and south. The bay is rimmed about with massive rocks; diorites cut by granite porphyry dikes on the west; diorite intrusive into amphibolites and hornblende granite on the south; and coarse hornblende granite on the east. These various rocks compose high encircling ridges; at the base of these a narrow and interrupted belt of variegated banded quartzites outcrops on all sides of the bay. On the west, to north and south of our anchorage at Summer Cove, the quartzites could be traced at least two miles along the shore, but they were never found more than about one hundred yards from the beach. The white, red, and purplish layers often exhibited the cross-bedding of a typical sandstone. The strike of the beds is variable, changing from N. 60° W. to N. 20° W., the dips remaining low and constantly directed toward the land. The total thickness of the beds exposed was measured at one hundred feet. The belt terminates at the mouth of the bay in a veritable museum of rock-types, the quartzites being cut by an interlacing network of granitic and trap dikes as well as by pegmatitic, aplitic and quartz veins. On the east side of the bay opposite Summer Cove, similar quartzites dipping 50° S. 70° E. occupy a second belt along the shore of about the same dimensions as those of the western shore-belt, excepting that the sediments are here exposed for only three hundred yards. At either end the belt is cut off by hornblende granite and hornblende gneiss on which the quartzite seems to have been deposited. All these rocks are cut by numerous wide and conspicuous dikes of augite porphyrite and squeezed amphibolitic trap. At the head of the bay, quartzites dipping 55° S. 35° W. were seen on a low spur projecting into a boulder-covered tidal flat.

In this case, as at Pomiadluk Point, diligent search failed to disclose fossiliferous evidence as to the horizon of the stratified deposits; at both localities there is the same general relation between eruptives and sediments, suggesting that the latter are, roughly at least, contemporaneous deposits.

Threading the maze of islands extending from Aillik Bay to Hopedale, no halt was made and no sampling of the coast geology could be carried on. From the somewhat monotonous character of the island-zone both as to color and form, it seemed to be composed of the coarse biotite gneiss which characterizes the rugged hills about Hopedale. Trap dikes were always in the view. Striped Island, twenty miles E. S. E. of Hopedale, owes its name to the curious contouring habit of twelve great dikes that have penetrated the granitic boss-like island along a nearly horizontal system of master-joints. They are now visible all around the clean-swept island but are particularly conspicuous on the west side for a distance of a half mile. At Hopedale, the wonderfully contorted gneiss, which is penetrated by numerous diabase dikes, has an average strike of N. 55° W. Thence northward, the archipelago of ragged sub-conical islands of the same gneissic composition extends with northwest trends to Ford Harbor on the east end of Paul's Island. Anchoring at Quirk Tickle, fifty miles north of Hopedale, we found the banded biotite gneiss with northwest strike and indistinguishable from the rock at Hopedale. Extending as it does a distance of at least one hundred and twenty miles along the coast, the Hopedale gneiss is one of the most important members of the whole crystalline complex.

The Nain gabbros. — The Hopedale gneiss underlies the eastern end of Paul's Island, but a few miles west of Ford Harbor, it comes in contact with the famous anorthosite and allied gabbro whence is derived the schillerizing labradorite. (Plate **11**). One may collect specimens of the feldspar from the numerous erratic boulders sprinkled over the hills about the harbor. The direction of glacial striation shows that these must have been carried to their present resting-places from the west and southwest. It was likewise made clear to us on the northward journey that the gabbro must be in great development in order to furnish such an immense amount of erratic material as we saw. Skirting the north shore of Paul's Island, the "Brave" was headed for Nain, passing through a long tickle walled in on either side by high cliffs of massive gabbro for fifteen miles before the mission station was reached. At the station we were still about twelve miles from a quarry where "precious" labradorite in place has been opened by Mr. R. G. Taber. The desire to see the mineral in place decided us to risk the schooner among the dangerous channels of the island-labyrinth. At Nain, however, we had the good fortune to find Dr. Wilfred Grenfell, superintendent of the Deep-sea Mission, then in command of his fine new steamer, the "Strathcona." With great kindness he invited our party to accompany him on the steamer to Mr. Taber's quarry; we thus spent one of the most enjoyable days of the summer in the accomplishment of what would have taken the schooner, by reason of the calms and baffling winds then prevailing, two or three days to effect. The quarry is situated on the southwest side of a small island called by the Eskimo, "Napoktulagatsuk." It lies within one fourth of a mile from the mainland.

Napoktulagatsuk is elliptical in shape and has a major axis of about six hundred yards. The opening has been made in a steep glaciated slope and covers an area of about twenty-five hundred square feet. At the foot of the slope a thirty-foot raised beach bears a ruined derrick, and a tramway which showed by their dilapidation that work has been discontinued for some years. While the whole island is composed of anorthosite, the schillerizing feldspar occurs only in the form of isolated patches up to fifty feet in diameter. These are generally, though not always, coarser in grain than the surrounding rock, and are pegmatitic in look. In the sunlight, the fresh surface of the rock presents a rich and beautiful appearance. The dominant color is the familiar blue, but it is associated with vivid green, bronze, orange, and red phases. These pocket-like schillerizing masses are clearly contemporaneous with their country-rock. Both types are characterized by the well-known composition of this gabbro. Both are cut by aplitic dikes and pegmatite veins.

The lofty dome-shaped islands situated between Nain and Napoktulagatsuk as well as all the mainland visible thereabouts are composed of the gabbro. There is every probability that the schillerizing phases may be found sporadically throughout this great area. They are known to occur on the eight hundred-foot Mt. Pikey, southwest of Ford Harbor. Peculiarly sombre in hue, profoundly glaciated and almost entirely devoid of vegetation, these great hummocks afford a scene of complete desolation almost without parallel even on the barren coast of Labrador.

Gneisses similar to those at Hopedale compose the outer islands north of Ford Harbor, but it is probable that the Nain gabbro is continuous with another great area that we first met with on Newark Island, and afterwards found extensively developed on the mainland at Port Manvers. At Black Island Harbor the gabbro is coarse; at Port Manvers it is finer-grained. In both cases the composition is identical with that characteristic of the Nain occurrence. The rock of this northern area has the habit of concentric weathering, boulders of disintegration forming great cyclopean walls on the glaciated ledges at Port Manvers. The rock seems to be much less resistant to the weather than the gneisses. The floors of glaciated valleys in the gabbro are invariably occupied with screes of the crumbling rock. A truly imposing example is seen in the long sweeping curve of waste that covers the lower fifteen hundred feet of the northern face of Mt. Thoresby.

The Kiglapait.

Fifteen miles north of Port Manvers the eastern end of the Kiglapait springs directly out of the sea. The name of this mountain-group is an Eskimo word meaning "The Great Sierra" and refers to the very ragged sky-line and general outlines. The axis of the range runs due east and west, parallel to the coast-line which here has an exceptional trend. The sierra is not more than thirty miles in length, but, on account of its conspicuous position on the shore, is strikingly picturesque. Ten distinct and individual summits from two thousand five hundred to four thousand feet in height could be counted from the schooner. No one of these, so far as the writer has been able to determine from missionaries, fishermen, or from the literature, has as yet received a name. Here, as in the higher mountains of the north, there is abundant opportunity for systematic field-work on the part of such an organization as the Appalachian Mountain Club.

We had hoped to spend some days, if not weeks, in the study of these interesting mountains, but the lateness of the season forbade our dropping anchor within reach of the noble range. Judging again simply from the peculiarly dark color of the bare rock-surfaces, it seems probable that the gabbro seen at Port Manvers makes up most of the Kiglapait, which will thus represent the Coolin type of gabbro mountains in Scotland.[1]

On the other hand, it was discovered that banded and much contorted gneisses compose the numerous low islands lying between Ford Harbor and Mugford Tickle, a distance of fifty miles. At the Tickle, the undulating platform of the complex disappears beneath the quite different formations of the Kaumajets.

The Kaumajet Mountain Group.

For a distance of fifty miles to the southward we had marked the majestic pile of the Bishop's Mitre with the associated mountains of the mainland. Their summits were at the time covered with a fresh fall of snow; the brilliancy of the crests recalled the etymology of the name which again illustrates the Eskimo's feeling for natural scenery. "Kaumajet" signifies "shining"; the range is the Himalaya of Labrador.

As indicated by its position, composition, and topographic character, the island of Ogua'lik really forms the southern extremity of the Kaumajets. Mugford Tickle separates it from the mainland. It was in this narrow channel that our anchorage was chosen. Again we had occasion to mourn the slowness of our northward progress, for it would have been of the highest interest to devote a fortnight at least to the exploration of this region; in order to be certain of reaching Nachvak, however, we allowed but two days in which to secure information concerning the nature of the massifs immediately surrounding the vessel.

The nine-hundred-foot scarps of Ogua'lik would have been impressive among the tamer landscapes of southern Labrador, but they were dwarfed beside the mighty walls of the opposing mountains only a mile or two distant. We had entered the tickle late at night, and in the brilliant starlight had discerned the huge piles looming up in solemn and formless grandeur. Their mystery became in part dispelled as a bright sun disclosed a scene in its way unrivalled in Labrador. Due north in the centre of the view two gracefully rounded knobs, estimated, by the aid of barometric readings half-way to their summits, to be

[1] A. Geikie, Scenery of Scotland. Ed. 2, 1887, p. 215.

two thousand five hundred feet in height, lay close to the verge of an almost vertical precipice from one thousand to one thousand two hundred feet high. Below this a series of lesser cliffs, separated by steeply sloping screes of rock-waste stepped downward to the uneven floor of a deep N. E.–S. W. valley. On the southeast the valley is bounded by a similar arrangement of cliffs and taluses. It ends as a great cul-de-sac two miles in length in a thousand-foot head-wall over which there cascades a large brook.

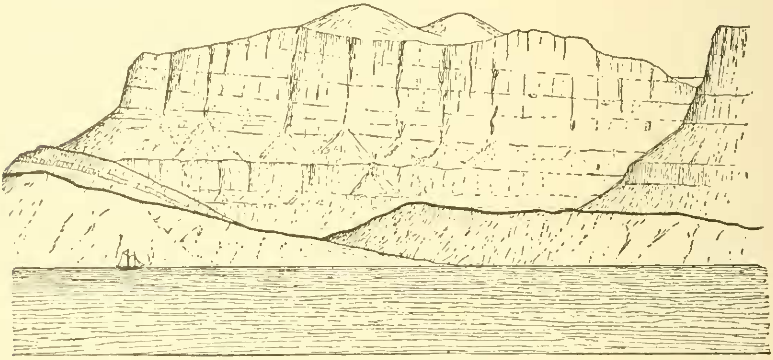

FIGURE 1. — Dissected plateau of Mugford sedimentary series, viewed from Mugford Tickle. Each of the two summit knobs was estimated to be about 2500 feet in elevation. Looking north. Drawn from a photograph. Heavy black line represents upper surface of the basement Complex.

On landing, we found that the first and natural impression, that this systematic array of scarps and taluses signified a stratified structure for the massif, was justified (Fig. 1 and Plate 11). At the foot of the great slope the basement of all the other rocks is represented in an irregular floor of contorted and faulted gneisses and amphibolites. The surface of the familiar complex appears at all elevations above the sea up to about six hundred feet. Next above the light colored zone of the schists comes a series of black slates fifty to one hundred feet thick, indurated at the contact by a conformable three hundred-foot sheet of apparently intrusive diabase. The edge of this sheet forms one of the lowest strong cliffs above the basement. The diabase in its turn is overlain by a great thickness of slates, quartzites, sandstones, quartz breccias, volcanic agglomerates, and trap layers. The inaccessibility of the cliffs and the shortness of the time allowed for examination rendered it impossible to determine the absolute strength of the various members. The enormous size and number of the blocks found in the screes seemed to show that the greater part of the thousand-foot cliff is made up, as they are, of a volcanic breccia. The basalt agglomerate, which is also a significant part of the stratified series, is typical and encloses numerous bombs with bread-crust structure.

These sediments and intercalated traps everywhere have low dips; therein we have an explanation of the plateau-like character of the relief, as dissimilar to any other on the coast, as the residuals of Torridonian sandstone are unlike the rolls of gneiss in the Scottish Highlands. Combining the observations made in the gorge below the waterfall, with those made in the Tickle and outside to the southeast of the Bishop's Mitre, the structure of the rocks on the northwest side of the Tickle is that of a flat syncline with a N. W.–S.E. axis, crossed, west of the waterfall, by a transverse warp. On the southwest, the effect is that of an eroded low half-dome. The steepest dips occur near the middle of the Tickle, where a magnificent section of the whole stratified series can be easily studied as the beds plunge into the deep water (Plate 1). The total thickness of the stratified series is about twenty-five hundred feet.

On Ogua'lik at the southwest end of the Tickle, the gneisses are overlain by an intrusive sheet of diabase, about fifty feet in thickness, upon which are piled slates, quartzites, limestones, and sandstones with interbedded traps. Whether the latter are intrusive or extrusive we had not time to determine, but the apparently complete absence of vesicular structure and of other signs of volcanic activity would speak for the latter interpretation. The limestone is rather crystalline, and is strongly charged with pyrite. A shallow opening and a few rusty tools showed that attempts had been made to test the rock for either gold or copper.

The whole of Ogua'lik corresponds in composition with these cliffs of the northwestern shore of the island. At the eastern end, black cliffs, fifteen hundred feet in height, form the edges of a capping massive sheet of trap estimated at seven hundred feet in thickness, overlying some nine hundred feet of sediments again unconformable on the gneissic complex. While there exists a general similarity between the formations on either side of Mugford Tickle, their failure to match on opposite sides of the strait seems to imply a fault coincident with it in direction.

The unconformity of the crystalline basement and the sediments is extremely well shown at both ends of the Tickle, especially at Cape Mugford itself (Plate 2). The gneisses have participated in the folding of the sedimentary cover; it is owing to that fact that they disappear in the middle cliffs of the strait. The surface of unconformity would, if produced, rise to seaward so as to pass completely over the fantastic peaks of Nanuktut Island. This island thus forms a strangely ragged outlier of the crystallines from which the sedimentary cover has been swept by denudation. The island has been called by the "Newfoundland Pilot" "the most remarkable and unmistakable land on the Labrador coast."[1] Nothing could exceed the contrast between its character and that of the Mugford massifs. The light gray precipitous two-thousand-foot peaks of the one oppose the black, tabular, greatly dissected piles of the other.

At Cape Mugford, which forms a nearly vertical sea-cliff about two thousand feet in height, we were struck with the highly ferruginous character of the sediments, broad bands of variously tinted iron-rust enriching and enlivening the color effects in a marked degree. Numerous waterfalls and extensive banks of snow lent welcome relief to the dark cliffs, the black recesses of huge sea-chasms, and the savage gorge-like inlets that opened one after another as our schooner slowly forged through the "tide" around the cape.

Fine as this scenery was, still greater magnificence awaited us as we came face to face with the Bishop's Mitre toward the close of a memorable day of sailing. Seen from the northeast, the mountain, estimated to be considerably more than three thousand feet in height, displays a symmetry which is most remarkable in view of the fact that the present profiles are everywhere the result of erosion. As the name implies, there are two peaked summits. They are separated by a sharp notch about five hundred feet in depth. This breach is but the uppermost part of a gigantic ravine that cleaves the mountain to its base at the shore more than two miles from the notch. Occupying the bottom of the ravine an uninterrupted snow-bank still marked, in the month of August, the line of symmetry of the whole mountain. From either peak of the Mitre a rugged razor-back ridge descends, each gradually diverging from the other across the widening intervening trench. With essentially equivalent transverse and longitudinal profiles, the two spurs further match as each terminates at an elevation of about one thousand feet, in a bold rock-tower. Each tower rises eight hundred feet or thereabouts above the ridge-crest and, on the east, drops suddenly the full eighteen hundred feet into the sea. The matching of the right and left halves of the mountain does not stop with the form. Each of the sentinel towers is composed above of black Mugford sediments reposing on five hundred feet of the light gray gneissic complex. The architectural quality of these great buttresses and of the Mitre itself is greatly enhanced when a fresh fall of snow brings out the nearly horizontal structure

[1] Newfoundland and Labrador Pilot (ed. 3, Hydrog. Office, London, 1897, p. 680).

of the whole massif and is such as to make one believe that the Mitre is the most beautiful single mountain on the coast.

About four miles to the westward of the Mitre is the summit of the highest mountain in the Mugford region; it was estimated to be in the vicinity of four thousand feet in elevation. A cone of simple yet effective outline, it is easily recognizable from a ship for a distance of seventy-five miles either north or south of Cape Mugford. So conspicuous is it that one cannot but wonder how it has been left so long neglected and left unnamed among the landmarks of the Admiralty charts. On board our own craft we fell into the habit of calling the peak "Brave Mountain," after the name of our doughty little schooner.

Pursuing our northward way tolerably close to land, it could be seen that for at least fifteen miles from Cape Mugford, the heavy sedimentary cover and its crystalline cover continued. Not the least important element in the imposing panorama was the "Finger Hill" of the charts, a long narrow plateau, perhaps two thousand feet in height, that stands close to the shore, and is evidently composed of the Mugford sediments. Its name is derived from a large number of tors or rock-pinnacles resulting from the dissection of the edges of nearly horizontal strata. Beyond Finger Hill, the coast turns sharply to the westward, and we could see no more of the Kaumajet. It is known that this range extends to the west and northwest of Cape Mugford, and it is presumably of sedimentary or volcanic origin over most of its extent. No fossils were found in any part of the Mugford series. Here, as in the Kiglapait, exploration is urgently needed.

From Finger Hill to Hebron we saw but little of the land. Going north, the "Brave" traversed this section of the coast during the night; returning, she remained at an average distance of five miles or more from the shore. Mainland and islands are relatively low, altitudes of one thousand or fifteen hundred feet being rarely surpassed. It was clear from the color of the rocks that the Mugford series does not compose this stretch of country; it is highly probable that it belongs entirely to the gneissic complex.

The Torngat Mountain Range.

Topography. — The triangular peninsula east of Ungava Bay is composed of two distinct topographic belts. On the west and southwest the land is caribou country, low, flat, grass- or moss-covered, with a considerable amount of stunted timber growing upon it. Rising abruptly out of this little elevated belt (charted as the "Kangiva") is the long, serrate chain of mountains, or strongly-dissected mountain plateau, extending one hundred and fifty miles north-northwest from Kangerdluksoak to Cape Chidley. In the southern part, the range has an average width of about fifty miles, but it narrows in the north. On the east, it is bordered throughout its extent by the Atlantic. Tectonically, the chain is closely related to the entire gneissic border of eastern Labrador, but its superior elevation and peculiar topography early marked it out as an orographic individual. Owing to the wild, forbidding, and awe-inspiring aspect of the mountain-wall, it is called by the Eskimo the home of the "Torngat," or "bad spirits."[1] Kohlmeister and Kmoch mention the name "Torngets" for the N. W. extremity of the ranges,[2] which was mapped as such by Weiz.[3] So far as the writer has been able to discover, the only other name for any part of the system is that given to the east-central portion, the "Nachwak Mountains" of Steinhauer,[4] or "Nachvak Mountains" of Kohlmeister and Kmoch.[5] There seems to be no good reason for regarding the whole highland belt as other than a structural and orographic unit. It is therefore proposed that the ancient name "Torngat" be extended so as to include all the belt from Hebron to Cape Chidley.

For a summary of what little is known concerning the Torngats, the reader is referred to "The Labrador Coast" of Packard.[6] Lieber, Bell, and Koch have respectively made local studies at Eclipse Harbor, Nachvak, and Ramah; all agree in emphasizing the wild, ragged, alpine nature of the relief. From end to end of the range, razor-back ridges and horns abound. These are separated by lower rounded hills and yet more conspicuously by numerous deep fiords and glaciated valleys or glens, the near relatives of the fiords. All three observers came to the conclusion that an alpine character has been preserved from preglacial times because the continental ice-cap did not cover the Torngats. Bell placed the average elevation of the local valley-glaciers of the ice-period at about two thousand feet above the present sealevel. As noted more fully below, this summer's observations correspond very closely with his estimates. It would be a mistake, however, to attribute a glacial origin to the rounded profiles of many of the dome-shaped mountains that alternate with the horns. The former are to be regarded as the result

[1] Translation due to Rev. A. Stecker.

[2] Journal, 1814, p. 50.

[3] A. S. Packard, The Labrador Coast, p. 226.

[4] H. Steinhauer, Trans. Geol. Soc. London, 1773, vol. 2, p. 488.

[5] Journal, p. 20.

[6] Pp. 3, 6, 19, 226.

of atmospheric erosion and their slopes as the graded surfaces of mountains normally subdued to relatively tame form by that agency. The same stage of development awaits their more acuminate neighbors. Glacial erosion has thus not only not reduced the higher summits to flowing outlines; by reason of the fact that glaciation has been confined to the valleys, it has even greatly steepened many slopes and given a more rugged aspect to the landscapes than belonged to them in preglacial times. One must ascribe a good share of the wild picturesqueness of the range to its profound trenching by valley-glaciers. During the glacial period, the Torngats seem to have formed a great dam facing the central névé of Labrador which thus lay on the Kangiva side. It was only here and there that ice-tongues crept over the low transverse passes, overflowed into the larger longitudinal valleys, and reached the Atlantic through the corresponding valleys on the east. At that time, the range appeared in the form of a large number of gigantic nunataks projecting from one to perhaps five thousand feet above the ice. There resulted among the salient features of the mountain-belt, the long east and west fiords, of which Nachvak Bay is doubtless the finest example.

THE GEOLOGY. — Crystalline schists form the principal constituents of the range. Near Hebron, the Johannesberg (2200 feet) is the loftiest of the high points which begin the chain on the south. At this mission station, the rocks were examined and found to be common biotite gneiss and amphibolites, intersected by trap dikes. The schists here trend due northwest, fairly conforming in attitude with the general trend of the southern Torngats. Bear Island, a half dozen miles to the eastward, exhibits a splendid exposure of the dikes. Similar, though much larger, ones can be traced on the cliffs all the way to Nachvak, a distance of seventy miles. They are usually vertical, often as much as three hundred feet in breadth and always in contrast with the schists into which they have been intruded. They are particularly developed on the flanks of Mt. Blow-me-down (*ca.* 3500 feet). The continued prevalence of these intrusives along the coast for the seven hundred miles from the Straits is, indeed, one of the most notable phenomena of its geology.

The Ramah Sedimentary Series. — The enterprise of Prof. Delabarre and Mr. Adams permits of the introduction at this place of some interesting data regarding a very extensive stratified cover which appears to bear the same relation to the crystalline complex as that of the Mugford sediments. They left the schooner at Hebron and walked over the mountains a distance of one hundred miles to the Hudson's Bay Post in Nachvak Bay, where they boarded the vessel again. They crossed the peninsula between Kangerdluksoak and Saeglek Bay and were carried by Eskimos across the latter inlet from the Pangnertok (see Weiz's map in Packard's "The Labrador Coast, p. 226). Thence they walked to Ramah Bay, were most hospitably received by the missionaries and after a much needed rest, went once more overland to their destination. They report that until they had reached a point three or four miles north of Saeglek Bay (at about 64° W. Long.), they passed over gneisses similar to those seen at Hebron. Then bands of black slate alternating with quartzite were met with. Soon continuous slates with interbedded sandstones and quartz breccias were crossed, and these persisted to a point some four miles north of Ramah Bay. Thence the route carried them over schists equivalent in character to those found on both sides of Nachvak Bay. The sediments are highly indurated, and often somewhat metamorphosed. Neither the quartzites nor the greatly cleaved and pyritiferous slates yielded fossils to the travellers, who were constantly on the lookout for them. What seems to be a continuation of the same sedimentary terrane was seen by the writer, though at a distance, in the form of ragged black cliffs fifteen hundred feet or more in height, lying southwest of Gulch Cape. The massifs corresponding are tabular, with very low dips and are plainly stratified. Kohlmeister and Kmoch mention the Ramah slates in the narrative of their journey in 1811.

Observations in and about Nachvak Bay. *Topography and Scenery.* — At dawn on August 21st, the "Brave" was lying-to about six miles from Gulch Cape waiting for daylight before the not particularly safe passage of the Nachvak Narrows could be attempted. As we drew nearer the shore, a brilliant sun flooded with light a scene most impressive to us who were fresh from the softened outlines of the southern coast and from the yet more featureless landscapes of southern New England. In front stood the bold fifteen hundred-foot headland whose many ravines have given the cape its name. Just west of it rose a curiously regular hill of about the same height, as typical a cone as one could well imagine, yet apparently an erosion form derived from the destruction of crystalline schists. To the right of the cone, a long east and west ridge, estimated at twenty-five hundred feet in height, claimed instant attention, as it represented, better than any part of the Torngats yet seen, that serrate topography which Bell and others have emphasized in the descriptions of the region. It is a knife-edged sierra, trenched on either flank and from top to bottom by a score of deep transverse ravines. In the background, visible through two U-shaped notches, appeared the stratified tables already referred to. Still farther to the north, the view included a lofty wall four miles long, interrupted by deep clefts and by one strong valley-notch. It ends abruptly at the Narrows of Nachvak Bay. About five hundred yards from the Narrows we lay some time becalmed close beside this cliff (the eastern slope of Karmârsuit), one of the grandest on the coast. It was estimated at approximately two thousand feet in altitude. With an angle of slope of about eighty degrees, with neither vegetation nor talus, it surpasses in its wild severity many more celebrated precipices of the world. About three miles northeast of the Narrows, a very perfect imitation of a volcanic cone was photographed and is here reproduced in Plate 5. Estimates gave the upper lip of the "crater" a height of two thousand feet above the sea; the depression itself a depth of one thousand feet or thereabouts. The amphitheatre seems to be an unusually good specimen of the glacial cirques which we were to find in great numbers wherever we had a chance to view the Torngats. Lieber noticed the frequency of similar forms on Aulatsivik Island. Finally, on the extreme right of the view, some fifteen miles from Gulch Cape, the coast was outlined by a sierra, "Mt. Razorback" (4000 feet, est.), one of the most rugged and most alpine, though not among the loftiest, members of the mountain-system.

Among the maps of Nachvak Bay which have yet been published, that of Weiz[1] is the best. While on board the schooner or in the skiff used in sounding, the writer made a rough sketch of the inlet which is believed to represent still more closely its true form. (Plate 12). For purposes of orientation, the Eskimo names for the more important landmarks have been inserted. These names we owe to Mr. George Ford, the Hudson's Bay agent at Nachvak, who, in this as in all other matters, was unwearied in affording us information about the country. The spelling of the names furnished by Rev. A. Stecker, originally in German, is phonetic after the sound of English vowels and consonants, and hence differs in a few instances from that adopted by Weiz.[2]

[1] See Packard, "The Labrador Coast," p. 226.

[2] The following is a glossary of names appearing in the sketch-map of Nachvak Bay, with their translations by Rev. A. Stecker of the Moravian Society.

Idyutak, "lever," referring to the form of the mountain.

Ivitak, "red-colored," land with a reddish color; red ochre; bricks.

Kaputyat, "place for trout-spearing," or (better) "place for spearing."

Karmârsuit, "wall." Some lands in the shape of a wall are called "Karmârsuk" (little wall) or "Karmârsoak" (great wall). "Suit" is a plural suffix. [*over*]

It will be seen from the map that the width of the bay averages about one and a half miles. Its length is twenty-five miles when measured to the head of either of the two arms, the Tallek, or the Tessyuyak. Weiz's map exaggerates both dimensions considerably. It is important to note that the trench filled with the salt water of the bay is continued at the head of each arm by a wide and deep glaciated valley. That corresponding to the Tallek runs to the south, its floor rising slowly, until, at a distance of about twenty miles from the Bay, it terminates in a flat divide adjacent to the valleys drained into Nullatatok and Saeglek Bays. The upper end of the Tessyuyak has been dammed across by a splendid alluvial fan that is growing vigorously out from the mouth of a hanging valley, the floor of which stands about one hundred feet above sealevel on the south wall of the inlet. The result has been the formation of a fresh-water lake, the Tessersoak, three miles long, which is drained by a rapid stream slightly trenching the fan. Beyond the lake to the westward, the deep valley extends with but little abated strength as far as the eye can follow it when viewed from the top of the fan. Mr. Ford informed us that the valley leads directly across the Torngats to the flat country on the west. The total length of this whole valley is thus about forty-five miles; rather more than half its floor lies beneath the sea.

On both sides the bay is walled in by very precipitous cliffs varying in height but averaging nearly two thousand feet above the sealevel. The highest point immediately overlooking the water is unquestionably the summit of the Idyutak, where its western face dominates the Tallek (Plates **3** and **4**). Its height (3400 feet, bar.) was long since

Kipsimarvik, meaning unknown; old Eskimo word perhaps, of which the meaning is lost, as in the case of many names of places.

Kogârsuk, "small brook."

Korlortoâluk, "big water-fall."

Kutyautak, "wedge," referring to the shape of the mountain.

Nachvak, "found, found at last." The first Eskimo, coming from the west in search of the salt water, cried out "Nachvak" when he reached the head of the bay.

Naksâluk, "great valley."

Sennerkitte, "tributary, branch stream."

Sittorutsit, "mountain side where avalanches are common."

Tallek, "arm," referring to the shape of the bay.

Tessersoak (also Tesseksoak), "large pond."

Tessyuyak, "like a pond."

Tinutyarvik, a basin at the head of a cove, barred off by a continuous wall-like shoal, so that at low tide fish are trapped as in a weir.

measured by Captain Bolton of the British Navy. On the opposite side of the Tallek is the slightly lower but equally majestic Kutyautak. The twenty-five-hundred-foot cliffs of the latter have slopes of from fifty to eighty degrees. Yet more imposing, perhaps, are the extremely rugged cliffs of the Tessyuyak near its head. They were estimated at twenty-five hundred feet in height on both shores. Their striking character is due not only to altitude and the narrowness of the bay, here but a half mile in width, but also to the greatly variegated color of the rocks. The usual neutral tones of the cliffs in the Torngats is exchanged for an irregular association of browns, reds, greens, yellows, slaty blue, grays and even white, according to the nature and condition of the schists or of the products of efflorescence.

While the fiord walls, varying thus from fifteen hundred to thirty-four hundred feet in height, are relatively continuous and enclose a well-defined trench, their sky-lines are often broken down by lateral notches. Some of them belong to glaciated valleys, the bed-rock floors of which lie below sealevel. Such inlets are more or less filled with deltas and alluvial fans built out by rapid brooks and torrents. Still more numerous are side-valleys that characteristically mouth at varying heights above the fiord waters. From Kipsimarvik (the Hudson's Bay Post) to the Narrows, twenty-two well developed cirques or corries from three to eight hundred yards in length were counted. The small streams draining them leave the corries at altitudes varying from one to two thousand feet above the sea. Identical in form and relations with the amphitheatres lining the larger glaciated valleys of the Alps, of Norway, of Scotland, and of the Rocky Mountains, they may best be explained as the result of very local but intense erosion of small ice-tributaries feeding the now vanished main glacier that once occupied Nachvak Bay. (*cf.* Plate 5.) Other "hanging valleys" of much greater dimensions are likewise found. The most important of these is drained by the large stream furnishing most of the water in the picturesque cascade "Korlortoâluk," two miles east of Kipsimarvik (Plate 6). The main leap of this fall was found by barometric means to be three hundred and seventy-five feet high; the total height of cascading water visible from the bay is five hundred and twenty-five feet, but the valley floor really appears at a height of seven hundred and fifty feet above the sea. The fiord is five hundred feet deep opposite the waterfall. There is thus a total discordance of twelve hundred and fifty feet in the altitude of the main and lateral valley floors. On an estimated gradient of two hundred feet to the mile, the lateral valley turns north-

northeast and thus runs nearly parallel to the Bay. The valley terminates, at a distance of eight or ten miles from the cascade, in a number of deep corries. Unlike the fiord, the lateral valley flares broadly and its floor is occupied by a half dozen lakes large and small. It is itself provided with two branch-valleys which join it just above the cascade. One of them ends in a glaciated col, the other in a magnificent cirque a mile in diameter. The drainage of these three valleys serves to sustain the waterfall all the year round.

It may also be noted that a fine series of cirques and hanging valleys look over the Kogârsuk. The most notable of these is the one whose drainage, forming the Sennerkitte brook, cascades more than two hundred feet into the Kogârsuk. It lies north of Mt. Ford, runs five miles or more to the eastward, and is floored over with a number of small lakes. (Plate **12.**)

An early statement of an explanation for these apparently abnormal valleys was given by Helland: "If a glacier fills a tributary valley, and is thinner than that in the main valley, the depth to which it erodes its bed must be less than the depth of the main valley. Hence many tributary valleys must debouch high above the bottom of the main valley. Instances abound of tributary valleys debouching thousands of feet above the beds of the main valleys along the steep sides of the fjords of western Norway."[1] Helland does not seem to have recognized the full significance of his idea in the general theory of glacial erosion; perhaps because he was so fully persuaded at the time of the competency of glaciers in this regard, that further emphasis was not necessary. The advantage of living on the ground may here have aided perception just as the ancient belief of the Swiss peasants long antedated the theory of Charpentier and Agassiz that the Swiss glaciers were once much greater than now. Davis, Gilbert, and Penck have recently and independently developed the idea to something like its full importance. Reference may be made to the detailed memoir of Davis for fuller information on this subject.[2]

Soundings showed that Nachvak Bay is an excellent type of fiord. Twenty-one casts of the lead sufficed to determine the submarine relief in its main features. (Plate **12.**) The greatest depth, of one hundred and ten fathoms, was found at a station six miles from the Narrows, where the water is nearly as deep. Two miles to seaward of the Narrows, the bottom shoals to an interrupted rock-sill which forms a long

[1] A. Helland, Quar. Jour. Geol. Soc., 1877, Vol. 33, p. 174.

[2] W. M. Davis, Proc. Bos. Nat. Hist., 1900, Vol. 29, p. 273.

line of breakers athwart the bay entrance. Ships generally enter the bay by a broad channel running from Gulch Cape close against the shore. The sill appears to be represented on its bottom where a sounding gave twenty-five fathoms of water. The sill thus rims about the mouth of the bay in a gentle curve. To the eastward the Admiralty charts indicate considerably shallower water than that in the bay itself. Up to a distance of twelve miles from the Narrows, the average depth of the bay is one hundred fathoms; then the bottom rises rapidly to a narrow bar running across the inlet. Upon it the maximum depth obtained was eighteen fathoms. The bar ends at either shore in a projecting spur of bed-rock; a fact that seemed to indicate that we have here to do with a rock-sill. Eight miles further west, a very similar sill crosses the bay, with a maximum depth of fifteen fathoms. To east and west of this bar, eighty and sixty-eight fathoms respectively were found. This coincidence in location of sills with constrictions in the fiord seems to be exceptional among the features of this type of inlet. A longitudinal profile of the bottom is given in Figure 2. The broadly U-shaped transverse profile of the Tallek is probably of the same general quality as the average cross-section of the whole fiord.

The extremely rapid destruction of the fiord walls, rendered so steep by glacial "over-deepening" has entailed the growth of abundant talus, and thereby the declivity of the submerged slopes has been diminished. This filling of the trench is particularly noticeable at the base of the numerous alluvial cones and fans which almost invariably appear where strong lateral ravines notch the cliffs. Creeping and leaping of the glacial drift down the slopes is going on apace. Large scallops or tongues of streaming clay,

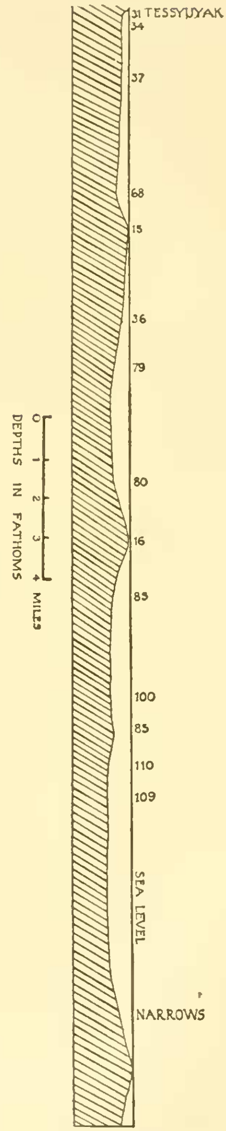

FIGURE 2. — Longitudinal section of Nachvak Bay.

gravel, and small boulders abound. Mr. Ford states that, after a heavy snowstorm, as many as twenty or thirty avalanches may, in the succeeding twenty-four hours be expected to fall within sight or sound of the Post. These slides always bring a greater or less amount of loose rock with them which, in winter, will find a temporary resting place on the frozen surface of the fiord, and gradually build a fringe of débris resting on the ice parallel to the shores. As might be expected, the number of these falls is greater in the spring than at any other time of the year. The marks made by the bounding boulders where they strike soft ground were found to be in the month of August, extremely fresh, and must have been formed only a few days previously. Mr. Palmer saw one boulder six feet in diameter fall from the wall of the Tallek, and, after its last rebound, leap fully a thousand feet before it struck the surface of the water. As in the Alps, there is a certain element of danger in travelling on these slopes.

It is not to the credit of American geographical enterprise that the Torngats are to-day unnamed, unmeasured, unknown in any scientific sense; yet they doubtless represent the highest land on the mainland of the American Atlantic seaboard from Hudson's Strait to Cape Horn. Lieber stated that "they are not less than 6,000 feet high, and some peaks may be 10,000 feet high." Koch later remarked that "the highest points of this range are opposite the island of Aulatsivik, and reach elevations of from 8,000 to 9,000 feet."[1]

One short fortnight was quite insufficient to permit of any exhaustive work on the determination of altitudes, especially as there were other and more important problems which engaged our attention while the "Brave" lay anchored at Kipsimarvik. Partly for this reason, only a few of the lower and nearer mountains were ascended. (Plate 12.)

Immediately back of the Hudson's Bay Post, on the northeast, a rounded knob was found, with the aid of two standard compensated aneroids, to be twenty-eight hundred feet above high water. It was called by our party "Mt. Elizabeth," after the young daughter of the Hudson's Bay agent. This mountain is separated by a profound notch from "Mt. Ford," named after the agent himself. It lies still farther to the northeastward; its altitude, determined again by the barometers, is thirty-nine hundred feet. From the summit a superb panorama is obtained on all sides. Due north, two conspicuous peaks some four miles distant across a deep east-west valley, cut off some of the view. The westernmost was ascended by Professor Delabarre and Mr. Adams and deter-

[1] Quoted by Packard, "The Labrador Coast," p. 228.

mined at forty-four hundred feet in height. This peak is, so far as known, the highest yet measured in Labrador. The other peak was not climbed, but was estimated by these gentlemen to be fifty-three hundred feet in height. Still higher summits dominate these on both sides of Nachvak Bay. From Mt. Ford the writer saw two extremely sharp horns, bearing N. 25° W. These must have been at least forty miles distant, and in all probability are members of the group of the "Four Peaks" mapped on the Admiralty chart as southwest of Eclipse Harbor. Judging from their conspicuous position in the sea of mountains, each of them must be at least seven thousand five hundred feet high. South of Nachvak Bay there are several fine peaks more than six thousand feet in altitude.

The Geology. — Bell has already given us some notes on the nature of the rocks in the bay. Additional observations made last summer could evidently not form a very complete or systematic piece of work. The Torngats, where examined along the long cross-section of the bay, are seen to be essentially composed of contorted but generally highly inclined crystalline schists, chiefly gneisses. The average strike is N. 25° W. At Skynner's Cove (Plate **12**) ledges of common gray biotite gneiss and dark-colored hornblende gneiss striking N. 5° W. are covered with many large boulders of an arkose-like rock enclosing roundish, often large, grains of opalescent quartz. This rock was not seen in place ; it may be related to a well-stratified, light colored rock series that occurs on the opposite side of the bay. The latter series is about five hundred feet in thickness, is manifestly sedimentary and lies unconformably upon the gneisses. Unfortunately there was no opportunity to make a landing and investigate the region closely. It may be that the cover represents a continuation of the stratified rocks seen southwest and west of Gulch Cape. The rocks of the Nachvak cliffs were sampled by Bell, who reported to have found there a slaty breccia apparently similar to the arkose of Skynner's Cove, and, as well, a "fine-grained silicious schist." [1]

Nine miles west of Skynner's Cove, on the north side of the bay, the well-banded gneisses still strike N. 5° W. ; they are here cut by a remarkable network of dikes exposed on a sheer fifteen hundred-foot cliff. The parallelism of the dikes gave them at first sight the look of sills, but closer examination showed that they are independent of the schistosity of the gneisses.

Near the Hudson's Bay Post, the rocks are chiefly coarse, friable

[1] Rep. Geol. Surv. Canada, 1882–3–4, Pt. DD, pp. 15, 16.

hornblende gneiss with abundant lenses of segregated hornblende and biotite. The strike varies from N. 15° W. to N. 30° W., and averages N. 25° W. From its trend, the Tallek was seen to be a strike-valley. The same may be said of the valley of the Kogârsuk, which mouths just west of Kipsimarvik. At the Post, thin sheets or dikes of eruptive rock cut the gneiss. They are light purplish-gray in color, and recall the anorthosites of the south. Gneiss similar to that at Kipsimarvik composes the northern and western slopes of the Kutyautak.

At the head of the Tessyuyak, the variegated cliffs proved to be in largest part made up of badly weathered ferruginous and silicious schists, graphite gneiss, and graphite schist. With these was associated in considerable development a peculiar breccia of angular quartz fragments embedded in a black corneous matrix. The graphite occurs abundantly in the form of disseminated flakes. No large mass of the pure mineral was discovered in the short time at our disposal. That such a discovery is possible appears from the fact that a rounded piece of pure graphite measuring four by five inches has been found at the foot of the talus near the great alluvial fan; it is now in the possession of Mr. Ford.

The General Structure of the Coastal Belt.

From the foregoing account, it may be seen that, in the line of the long coastal section from Belle Isle Strait to Nachvak, Labrador is underlain by the crystalline complex. If, now, a review is made of the most important structural element, strike-direction, one cannot but conclude that the Archæan shield is rather definitely framed on this border, and that the average direction of the coast-line is related to the tectonic trend of the ancient mountain-system of which the Labrador plateau is a diminished remnant. (Plate **11**, Table I.). A similar parallelism of structural trend and coast-line probably exists along the high mountain-belt of eastern Baffin Land as far as Lancaster Sound.[1] It should be stated that the brief table and the map do not represent the only evidence for this law as expressed in Labrador. Very often the general attitude of the crystalline schists could be determined from the schooner when under way, although no opportunity could then present itself for accurate measurement of the strike. The impression thus gained is sufficient to warrant our regarding the fidelity of the structure to a general N. W.–S. E. trend as of a higher order than is shown in the table or in the sketch-map. On the other hand, it is evident that no record

[1] E. Suess, La Face de la Terre, 1900, vol. 2, p. 47.

TABLE I.

STRIKE-DIRECTIONS (TRUE) IN NEWFOUNDLAND AND LABRADOR.

Locality.	Character of Rocks.	Strike.	Remarks.
Great Bréhat, Newfoundland	slates, sandstones	N. 65° W.	stratification
Great Bréhat, Newfoundland	slates, sandstones	N. 35° E.	slaty cleavage
Fortune Bay, Newfoundland	slates	N. 25° E.	stratification
Kirpon Harbor, Newfoundland	slates and sandstones	N. 20°–30° E.	stratification
Assizes Harbor, Labrador	gneiss	N. 57°–82° E.	average N. 70° E.
St. Francis Harbor	gneiss	N. 45°–65° W.	average N. 60° W.
Pottle's Cove, West Bay	gneiss	N. 60° W.	linear parallel structure
Ice Tickle	gneiss	N. 85° W.	
Summer Cove, Aillik Bay	quartzitic sandstone	N. 20°–60° W.	stratification
Head of Aillik Bay	quartzite	N. 35° W.	stratification
Hopedale	gneiss	N. 55° W.	gneiss contorted
Quirk Tickle, 25 miles S. of Ford Harbor	gneiss	N. 45° W.	
Ford Harbor	gneiss	N. 5° E.	gneiss contorted
Island 2 miles N. of Ford Harbor	gneiss	N. 90° E.	
Island 6 miles N. of Ford Harbor	gneiss	N. 5° W.	
Cutthroat Tickle, 25 miles N. of Port Manvers	gneiss	N. 30° E.	gneiss contorted
Mugford Tickle	gneissic floor	ca. N. 45° W.	gneiss contorted
Mugford Tickle	sedimentary cover	ca. N. 45° W.	strike generalized
Hebron	gneiss, amphibolite	N. 45° W.	
Skynner's Cove, Nachvak Bay	gneisses	N. 5° W.	
Nine miles W. of Skynner's Cove, Nachvak Bay, north side	gneisses	N. 5° W.	
Great Cascade, Nachvak Bay	gneiss	N. 30°–35° W.	
Kipsimarvik	gneisses	N. 15°–30° W.	average N. 25° W.
Five miles from head of the Tessyuyak, Nachvak Bay, south side	gneiss	N. 35° W.	

of the tectonic axis of the system can be made in the broad areas of eruptive granites, diorites and gabbros so plentifully distributed along the coast. In the northern part, from Cape Chidley to Cape Mugford, the structural trend is represented in the present day topography of the Torngats and, to a less degree, of the Kaumajets. Elsewhere, there are only subordinate ranges of hills the directions of which lie parallel to the strike. The peculiar attitude of the east-west crest-line of the Kiglapait cannot be explained until the constitution of that range is known.

It would be of great interest to determine the relation between this Labrador trend and the structural axes of the Appalachian system. A hint of that relation was suggested by the structures observed at Great Bréhat Harbor in Newfoundland (twenty miles south of Cape Bauld). There a series of slates and feldspathic sandstones of unknown age but very similar to the Cambrian (?) sediments of Kirpon, shows stratification striking on the average N. 65° W. while a later and beautifully developed slaty cleavage strikes N. 35° E. The cleavage has an Appalachian trend; the folds show what may be regarded as the Labrador trend. If the future survey of northern Newfoundland proves that this association of structures is general, it may not be too bold to consider the region as at the nodal point of intersection of the two master structure lines of eastern North America.

These structural lines are likewise related respectively to the Labrador and Appalachian continental shelves which are so typically developed. Where the two shelves meet, we have the Grand Bank of Newfoundland. Although not accentuated among the theories of the Bank so far formulated, the possibility that the plateau on which it stands owes its origin to tectonic movements at the intersection of the Labrador and Appalachian structural axes, should not be overlooked. Thoulet seems to have thrown final discredit on the older view of Maury that the Bank has been built up from the deep sea by iceberg droppings; but Thoulet's replacing icebergs by coast-ice as the carrying agents still leaves the question open as to whether the materials dredged up from the Bank may not represent but a very shallow veneer coating the surface of a submerged mountain-plateau.

Observations on the Surface Geology.

The most important problems in connection with the surface geology of the coastal belt relate to glaciation and postglacial crustal movements. These processes became most interesting, perhaps, when viewed in the light of their effects on the existing topography. Among the incentives which the writer had to join the expedition was the need of more detailed observations than had yet been made on the general direction of ice-movement in glacial times; on the question of the non-glaciation of the high northern mountains; and on the "lunoid furrows" that were long ago found on the coast by Packard. The amount and character of postglacial uplift, the elevated beaches and other shore-forms associated with that emergence likewise invited as close study as time and circumstances would permit.

Glacial Markings; Direction of Ice-Movement.

Several visitors to the coast have repeatedly emphasized the difficulty of discovering there the glacial striæ and grooves which should normally appear on ledges so strongly ice-worn as those of Labrador. For this reason, it had been anticipated that our necessarily short halts at the different anchorages would not permit of our adding many localities to the few where the course of ice-movement has been determined. It was therefore an agreeable surprise to find ice-markings at nearly every landing place and often in great abundance. The intense power of the frost has, in postglacial time, certainly caused some obliteration of such records; but the non-discovery of these is much more likely to have been occasioned by the fact that search seems to have been hitherto largely confined to the shore-zone recently emerged from the sea. The evidence and amount of this emergence will be considered in the sequel. In the southern part of the coastal belt, it is only the higher points which, during the maximum postglacial depression of the land, remained above the sea. As the land arose, wave-action, coast-ice and the exceptional power of frost in the zone of flying spray, have tended to cause the destruction of all glacial marks within the belt of land thus exposed.

Selected readings of the directions followed by glacial striation are given in the following table (Table II.), and are plotted on the map. (Plate **13**.) It will be seen that at all elevations, both in the valleys and on the hill-tops, the ice-movement was outward from the central part of the peninsula. The result is to confirm the conclusion which has been based on five recorded single observations made at Hamilton Inlet, Indian Island, Davis Inlet, Nain, and Nachvak.[1]

Glacial Lunoid Furrows. — Chamberlin has shown, by the collection of many examples, that glacial markings *transverse* to the course of the

[1] R. Bell, Scot. Geog. Mag. 1895, vol. 11, map accompanying text.

TABLE II.

Directions of Ice-Movement as shown by Grooves, Striæ, and Lunoid Furrows.

Locality.	Grooves and Striæ.		Lunoid Furrows.			
	Altitude in feet above High Water.	Direction (true).	Altitude in feet.	Character of bed-rock.	Occurrence: single (si), in series (se).	Direction (convexity downstream).
St. John's, Newfoundland	400	N. 90° E.				
Newell's Island, Greenspond, Newfoundland	6	S. 70° E.				
Fortune Bay, near Cape Bauld, Newfoundland	3	S. 20° E.				
St. Francis Harbor	5	S. 82° E.				
Head of West Bay	2	S. 85° E.				
New Harbor, near Tub Harbor	3	N. 85° W.				
Bake Apple Bight, Rodney Mundy Island	5	N. 55°–60° E.	5	fine-grained gneiss	si and se	N. 55°–60° E.
do.	20	N. 70° E.	20	do.	si	N. 70° E.
SW. side Rodney Mundy Id.	ca. 50	N. 55° E.	ca. 50	coarse gneiss and granitite	si	N. 55° E.
W. shore Sloop Harbor (Brig Harbor)	. . .	. . . . . .	250	coarse granitite	si and se	N. 65° E.
SW. flank of 335′ hill, Sloop Harbor	250	N. 80° E.	250	do.	si and se	N. 80° E.
Mainland NW. of Conical Id.	290	N. 25°–30° E.				
Ridge 3 miles W. of Pomiadluk Point	. . .	. . . . . .	250	granitite	si and se	N. 35° E.
do.	1170	N 30° E.	1170	do.	si	variable
Summer Cove, Aillik Bay	50	N. 35° E.	50	diorite	si and se	N. 35° E.
do.	200	N. 38°–40° E.	200	do.	si	N. 40° E.
E. side Aillik Bay	100	N. 40° E.				

TABLE II. (*continued*).

Locality.	Grooves and Striæ.		Lunoid Furrows.			
	Altitude in feet above High Water.	Direction (true).	Altitude in feet.	Character of bed-rock.	Occurrence: single (si), in series (se).	Direction (convexity downstream).
Head of Aillik Bay	1000	N. 40° E.	1000	hornblende granite	si and se	N. 20°–40° E.
Hopedale	ca. 375	N. 29° E.	ca. 375	gneiss.	si	N. 40° E.
do.	ca. 375	N. 32° E.	do.	do.	si	N. 52° E.
do.	. . .	. . . . . .	do.	do.	se	N. 55° E.
do.	ca. 275	N. 43° E.	do.	do.	se	N. 43° E.
do.	. . .	. . . . . .	do.	do.	se	N. 30° E.
do.	. . .	. . . . . .	do.	do.	se	N. 35° E.
do.	. . .	. . . . . .	do.	trap dike	se	N. 37° E.
Quirk Tickle, 25 miles S. of Ford Harbor	300	N. 59°–62° E.	300	gneiss	si and se	N. 60° E.
Ford Harbor	295	N. 56° E.	295	gneiss	si	N. 50° E.
do.	380	N. 56° E.	390	gneiss	si	N. 43°–55° E.
Island 2½ miles N. of Ford Harbor	250	N. 65° E.	250	gneiss	si and se	N. 65° E.
do.	250	N. 53° E.	250	quartz vein	si and se	N. 65° E.
Port Manvers	2	N. 50° E.				
do.	300	N. 42° E.				
Cutthroat Tickle, 25 miles N. of Port Manvers	. .	. . . . . .	ca. 50	gneiss	si	N. 40° E.
Mugford Tickle	630	N. 85° E.[1]				
Hebron	ca. 100	N. 45° E.				
Kipsimarvik, Nachvak Bay .	200	S. 70° E.[1]	200	gneiss	si	N. 70° E.
Great Cascade, Nachvak Bay	700	S.[1]	700	gneiss	si	S.

[1] Corresponding to the local character of the glaciation at these localities, the striæ and furrows have varying trends.

ice are of frequent occurrence.[1] In every case, the marking is typically curved and of lunate pattern, the convex side of the curve being directed upstream in the one class of markings, downstream in the other. There have yet lacked both criteria to distinguish the one division from the other and information as to the relative frequency of either kind in nature. Consequently, it has been hitherto impossible to use these cross-markings extensively as indications of the direction of ice-movement. With considerable interest and care the coastal belt was examined for light on the question.

Packard has described and figured the "glacial lunoid furrows" occurring at Indian Tickle just north of Hamilton Inlet. "These crescent-shaped depressions, which run transversely to the course of the bay, were from five to fourteen inches broad by three to nine inches long, and about an inch deep vertically in the rock. Their inner or concave edge pointed southwest, the bay running in a general S. W. and N. E. direction. They were scattered irregularly over a surface twenty feet square. When several followed in a line, two large ones were often succeeded by a couple one quarter as large or *vice versa*." [2] We owe the name "lunoid furrows" to De Laski, who gave the first clear account of them as they appear on the ledges about Penobscot Bay. The furrows are there from one inch to four or five feet in breadth. "They are lunate in figure, . . . their steep walls invariably looking towards the north, never directed *south* as stated in the "*Reports on the Scientific Survey*" [of Maine] for 1862, p. 383."[3] His furrows seem to be equivalent with the "crescentic gouges," "jumping gouges," and "disrupted gouges" of Chamberlin.

It was not far from Indian Tickle that the present writer also found the lunoid markings for the first time. At Bake Apple Bight on Rodney Mundy Island, excellent examples were discovered. The lunoid depressions, measuring from two to fifteen inches from horn to horn and from one quarter to one and a half inches deep in the middle of the curve, presented an appearance essentially similar to that described by Packard. The two slopes of the depression were always unequal. The longer one made an angle of from two to twenty degrees with the general surface of the *roche moutonnée ;* the other, limited above by the convex line bounding the marking in plan, made angles of from fifty to ninety degrees with the general ledge surface. The furrows or lunes occurred singly and

[1] T. C. Chamberlin, U. S. Geol Sur., 7th Ann. Rept., 1885–86, p. 218–223.

[2] The Labrador Coast, p. 298.

[3] J. De Laski, Amer. Jour. Sci., 1864, ser. 2, vol. 37, p. 337.

also aligned in series. In both cases the axis of symmetry and the convex side of the curved pit were directed N. 55°–60° E. What made this locality of particular interest was the fact that one series of seven furrows lay on the stoss side of a ledge covered with undoubted glacial striæ and grooves. These were seen to lie in the axis of the lunes. The trend of the striæ was likewise N. 55°–60° E. Such a relation of parallelism between lune-axes and striæ was a strong witness to the glacial origin of the lunes, and it was found to exist in the case of the great majority of them at each locality on the coast. (See Table II.)

The best exposures of the lunes discovered during the summer are at Pomiadluk Point, at Aillik Bay and at Hopedale. (Plate 7.) At the head of Aillik Bay near the highest of the elevated shore-lines, a fine group of naked, highly polished *roches moutonnées* are marked with numerous lunes from two to three feet in span. On the east side of the bay at the shore near the prominent trap dikes opposite Summer Cove, the serial arrangement of the lunes is exceptionally well developed. In one instance twelve, and in another fifteen, of them were seen in line.

Single lunes, very rarely lunes grouped in series, are sometimes so situated that their axes of symmetry are widely divergent from the accompanying lines of striation. Such an attitude is, however, quite exceptional, and in general, the perfection of the lunate form is greatest when the axis of symmetry is orientated parallel to the striæ and grooves. Like the latter, the lunes were found most commonly on the stoss side of the glaciated ledge. As in Maine, the convex side of the lune is always directed downstream with reference to the moving ice-sheet that formed the grooves. This is true in the south and also at Nachvak where the glaciation was but local.

There seems to be no reasonable interpretation of the lunes that does not assign their location to glacial action. But it is difficult to imagine how either clean ice or boulders caught in the ice and dragged over a ledge could produce the actual furrow. From a somewhat prolonged study of the typical examples at Hopedale, the writer was led to believe that these lunes were only potential when the ice-sheet disappeared and to extend the same idea to all such furrows. The tension or shearing stress set up in the bed-rock by a boulder dragged along beneath the ice, must oftentimes be enormous. This must be so if boulders are really responsible for the deep striation and grooving of glaciated ledges. Such shearing stress may be easily conceived to be here and there partly relieved by the development of incipient cracks dipping gently forward and, at the same time, sloping inward from each side toward the line traced by the boulder. The formation of such a crack would, of course, be facilitated by a pre-existing tendency of the rock to exfoliate following surfaces parallel to the crack, but such a coincidence would be very rare. The integrity of the rock-surface will henceforth be endangered because frost can work upon these cracks in the same manner as it works on joint-planes. The actual hollows would thus owe their existence to the postglacial splitting action of frost, prying up and breaking off prismatic fragments of the rock until these fragments had reached a thickness appropriate to the steep inner face of the lune. The size of the lune is limited by the distance measured along the crack through which the rock has been rendered unsound.

The detailed features of the lunes seem to bear out this hypothesis. In every perfect or only partially completed furrow, a thin crack forms the prolongation of the gently sloping floor of the depression and is extended into the yet undisturbed rock at the horns where, in a little distance, the cracks disappear entirely. There is often a very decided difference in the freshness of the rock exposed on the steep and gentle slopes of the lune respectively. The latter may be distinctly weathered and lichen-covered, the former almost perfectly fresh and evidently so recently formed that no plant-life has had a chance to secure a foothold on the unaltered surface. This contrast between the two slopes is explicable by the hypothesis proposed ; it forms a difficulty in the way of accepting any view which would derive a given lune in its present form from the direct action of the ice or its graving-tool.

While it may be anticipated that most lunes will be developed in parallel orientation with grooves, it will, by the shear-hypothesis, be no less certainly expected that tensions will be set up by many boulders not travelling in the direction of general ice-movement, and that lunes with quite different orientations will result. As we have seen already, the facts agree with this expectation. A further cause for the typical development of furrows may be looked for in the structure of the rock on which they occur. It may be for this reason that the lunes of Hopedale are so well fashioned. There the glacial grooves cut across the schistosity of the gneisses which will doubtless *tear* apart most easily in that transverse direction. Where the schistosity is not at right angles to the line joining lunes in sequence, the lunes are sometimes accordantly unsymmetrical, as if there were a tendency to exfoliation in a direction oblique to that line. Yet structure must play but a subordinate part in the manufacture of lunes, for they are found on such widely different rocks as the fine to medium-grained gneisses, coarse granitoid gneiss and coarse granite of Rodney Mundy Island, the granitites of Sloop Harbor and Pomiadluk Point, the diorite of Aillik Bay, the gneiss and trap of Hopedale and the vein quartz as exposed near Ford Harbor. Each rock has evidently acted as a more or less homogeneous body with reference to the deforming force.

Finally, it should be noted that postglacial frost is not of itself sufficient to produce the systematic form and arrangement of the lunoid markings. Examination of many ledges in Labrador on surfaces exposed by rifting since the ice epoch, failed to disclose anything similar to the phenomena described. To be sure, the familiar rough surfaces of ledges cleft by frost acting on structural and less regular cracks, is sufficiently analogous to the surface of a *roche moutonnée* covered with lunes, to suggest frost as the common cause for the damage done, but the irregular depressions of the first class lack the peculiar form and orientation of the second.

This explanation of the lunes naturally suggested experiment, but little has been done in that direction. When glass is scratched with a diamond point, a multitude of curved transverse cracks is generally produced. They are always short, highly inclined, and recall in a significant way the "serrated striæ" of Andrews,[1] the "cross-fractures" of N. H. Winchell,[2] the "crescentic cross-fractures" and "crescentic cracks" described by Chamberlin. They may be allied to "chatter-marks" as well. Russell has described others in the Sierra Nevada.[3] The convexities of these curved cracks are always symmetrical to the glacial striæ and are directed upstream, just as the convexities of the cracks in the glass of the experiment are symmetrical and directed in the sense opposite to the movement of the diamond. The "crescentic cracks" were seen in several localities in immediate association with lunes, but with an invariably reversed attitude of the convexities. The former class of markings, though commonly arranged in series, are much rarer than the lunes, and seldom appear on any but the finer-grained and more brittle rocks, quartzites, slates, and traps. They are usually under three inches in length and thus much smaller than the lunes. Being simply cracks, they do not form distinct hollows in the rock. Their steep inclination doubtless explains the fact that the frost has not produced such depressions as are likely to be developed where a crack has a low dip into the rock-surface.

While thus this experiment does not throw direct light on the interpretation of the lunoid furrows, it yet suggests an explanation for a related

[1] E. Andrews, Amer. Jour. Sci. 1883, ser. 3, vol. 26, p. 101.

[2] Geol. Nat. Hist. Sur. Minn., 1884, vol. 1, p. 548.

[3] I. C. Russell, U. S. Geol., Sur. 8th Ann. Rept., 1889, p. 367.

group of markings, and affords reason to believe that both groups are effects of the release of shearing stresses set up in the *roche moutonnée* by a striating boulder.

Packard's early theory of the furrows has been amended to a form which may be stated in his own words:

"The curved and crescentic or gouge shape of the mark appears to be due to the fact (1) that the glacier carried or pushed a more or less angular boulder over a granite nubble or spur, so that the pressure was greater than at other points in the valley [the Aar Valley]; (2) the more or less rounded boulder, with its lower or under side perhaps somewhat flat, and so situated that the ice rested only on the top, occasioned greater local pressure than where no boulders were present; (3) the boulder meeting with a slight obstacle suddenly stopped, and the ice pushing it from behind caused it to slightly tip, so that an immense pressure was brought to bear on the small surface, causing the formation of a gouge-like crescentic hollow, with the concavity towards the origin of the motion, *i.e.*, facing up the valley.

"In making my first explanation I wrongly inferred that there might be an 'advancing and receding motion of the glacier,' so as to cause the stone to turn over.

"In some way, then, due both to the striking or pushing force of the glacier, and to the local pressure resulting from the presence of a boulder between the ice and the rock-surface, the boulder was not as with the rest of the ground-moraine, pushed gradually and slowly onward, but hitched, thus causing it to break off the lunoid fragment on a surface peculiarly liable, under great local pressure, to exfoliate." [1]

If the writer correctly understand Packard's view, both his hypothesis and the shear hypothesis agree in removing the furrows from the category of "chatter-marks," which imply that the gouging-tool must have been lifted clear of the rock-surface in order to deliver its smiting blow. That true lunoid furrows may be formed at intervals along an otherwise continuous groove is shown in Figs. 32, 33, and 34 of Chamberlin's classic paper.[2] It is clear, in each case, that the boulder must have pressed the ledge with great force as it traversed the inter-furrow space. Packard makes the hollow as well as the tendency to exfoliate date from the time of the actual passage of the boulder over the rock; but he does not show how localized downward pressure could produce a crescentiform hollow with a steep scarp facing upstream.

The main conclusions from these considerations are: First, that crescentic cracks and lunoid furrows may be distinguished in the field; secondly, that while often very abundant, they form valuable criteria

[1] Amer. Geol., Feb. 1890, p. 105.

[2] U. S. Geol. Surv., 7th Ann. Rept., 1885–86, p. 219–220.

for the direction of ice-motion in a region once glaciated, and still strongly frost-bitten in the winter-season at least; and, lastly, that both kinds of marking may be regarded as directly or indirectly the product of shearing stress set up in bed-rock at the gouging corner of a boulder held in the advancing ice.

The Glacial Deposits.

Nothing is more striking in the glacial geology of the southern part of the coastal belt than the almost complete absence of drift deposits. Above the highest shore-line registering the limit of postglacial submergence, isolated boulders resting on bare rock, or small patches of till a few inches or feet in thickness, represent the only glacial accumulations seen at any of our landing-places save one of all those south of Nachvak Bay. North of Cape Porcupine and elsewhere, it is true, washed drift that has been assorted and collected in the form of bay-plains and beaches now elevated, were found; but extensive deposits either directly ice-laid or distributed by glacial streams, normally failed. The exception referred to, applies to a small but well-defined frontal moraine situated on the mainland opposite Copper Island near Seal Island Harbor. Approaching the mainland through a narrow tickle, we were struck by the sight of a flat-topped terrace, steeply scarped at the shore. This cliff, averaging some fifty feet in height, was found to be composed of typical till strongly charged with boulders of gnarled schists and gneisses, a peculiar hornblende syenite, micaceous trap, pegmatite, aplite and vein quartz. The beach facing the moraine had greater variety of composition than any other noted during the summer. Most of the boulders were clearly erratic. The moraine is bilobate in plan, the curved ridge trending roughly north and south. It is a curving wall one hundred feet in maximum height and about a mile and a half in length. The concave side of the curve looks toward the mouth of a strong east–west valley opening toward the sea through a range of hills. The latter approach one thousand feet in altitude and seem to have harbored at least this one valley glacier in the closing stage of the ice period. On account of the rarity of such deposits, and on account of its fine development, it would have been of interest to study it in greater detail, but no opportunity to do so was afforded.

The Glaciation of the Torngats.

In 1860, Lieber noted that on the mainland opposite Aulatsivik Island, "wild volcanic-looking mountains form a water-shed in the interior, whose craggy peaks have evidently never been ground down by land-ice into domes and rounded tops." Bell, in 1884, published his observations on the Torngats. He stated: "The mountains around Nachvak are steep, rough-sided, peaked, and serrated, and have no appearance of having been glaciated, excepting close to the sea-level. The rocks are softened, eroded, and deeply decayed. . . . Throughout the drift period, the top of the coast range of the Labrador stood above the ice and was not glaciated, especially the high northern part." [1]

But this serrate topography is not of itself sufficient to disprove that the glaciation was general in the Torngats; it implies with certainty only that the glaciation of the range was *weak* at higher levels at the time when the hummocky plateau of southern Labrador was remodelled by the ice. Tarr has shown that, notwithstanding the angularity of its summits, Mt. Ktaadn in Maine was completely covered by ice in the last glacial epoch. The present form is understood in the light of the facts that Tarr has emphasized: (1) The rapidity of frost attack is so great at high altitudes that the shape of a glaciated knob may be significantly changed even in postglacial time. (2) The summits have been longer exposed to the weather than the valleys, since the latter would be occupied by local glaciers during late glacial time. (3) Although the summit was ice-covered, it would presumably be above the zone of maximum glaciation. (4) The lack of timber in the higher parts of the mountain would give the weather permission to produce serrate topography which would not be expected in the lower vegetated belt.[2] In summarizing the results of his studies of the Cornell glacier, Tarr notes further strictures on the same criterion of non-glaciation.[3] He states in effect that we should expect less erosion by ice in the higher parts, because of the slower motion of the ice in the upstream portion, and because of the clean character of the ice above the débris zone. The valleys should necessarily show more intense erosion than the mountain-tops, since thick glacier ice would appear first in the valleys as the ice-cap waxes, and still exists there after the waning ice-cap had deserted the summits. He has, moreover, found erratics on Mt. Schurmann, a ragged nunatak in the Cornell glacier. Lastly, he notes that serrateness may be only apparent, the impression of raggedness being due to the common position of the observer on the lee or down-stream side of a glaciated headland, as he approaches such a coast as that of West Greenland. While

[1] Rep. Geol. Sur. Canada, 1884, Part DD, pp. 14 and 37; cf. Report for 1885, Part DD, p. 7, and Scottish Geog. Mag., Vol. 11, 1895, p. 340.

[2] R. S. Tarr, Bull. Geol. Soc. Amer., 1900, Vol. 11, p. 437.

[3] Bull. Geol. Soc. Amer., 1897, Vol. 8, p. 252.

it is true that the serrateness of the Torngats is real and extensively developed, it will be well to present the evidence now in hand, which shows that, above a certain relatively low line, the range was, during the last advance of the great ice-sheet, not covered by a glacial mantle differing in any important way from the snow-blanket which overlies the country during the present winters.

It is important to note that the discussion of the question will refer simply to the last advance of the ice. Until it has been determined whether there was once an interglacial period in Labrador corresponding to that recorded in the United States and southern Canada, we cannot be sure that a glacial topography, developed during the first advance, was not destroyed during interglacial time and during the time occupied in the second advance. It seems probable that the interglacial interval was longer near the zone of great terminal moraines than in Canada. Still further north the ice may have lain on the country throughout the whole glacial epoch. On the other hand, the Torngats may hold exactly the same relation to the rest of the peninsula as that of the Lofoden Islands to the Scandinavian mainland. An Alpine relief characterizes the island group to-day, although the ice-cap of the first glacial advance ran over the group far out into the Atlantic.

The first attempt to solve the problem was made on the slopes of Mt. Ford. Ascending the mountain on the west side, typical *roches moutonnées* and undoubted erratics cease at the sixteen hundred-foot contour. Above this, to the summit, the slope is one continuous Felsenmeer. Although unremitting search was carried on during the ascent, not a single erratic piece of rock was discovered above the contour mentioned. The creeping, frost-driven and snow-driven, fragments of ferruginous gneisses, trap, vein quartz, and syenite were found to be universally sharp-cornered, never subangular, and always deeply weathered. The few ledges protruding through the Felsenmeer were likewise profoundly affected by frost and general weathering, and nowhere presented the familiar smooth surface of a glaciated nubble of rock. While these contrasts between the Felsenmeer fragments and decayed ledges above and the fresh subangular erratics and *roches moutonnées* less than five hundred feet below, were very marked, there yet remained the possibility that the Felsenmeer really covered well glaciated bed-rock over which the rock fragments have streamed in postglacial times. The rarity of the ledges between sixteen hundred feet and the summit was such as not to permit of a satisfactory conclusion based on the study of this one mountain-slope. On the south side, where the descent of Mt. Ford was made toward the cascade, more significant testimony was furnished by the ledges. Two of these, each from one to two acres in extent, occur on the *flat* top of spurs measured at thirty-two hundred and twenty-five hundred feet respectively. In both cases the outcropping rock is a decomposed, light-colored gneiss cut by numerous wide bands of black trap. Each spur-top is separated from the main mountain by a col; rock-slides or snow-slides would not sweep over the spurs from the higher slopes, and thus disturb from their original positions any erratics that may have been dropped on the spurs by a glacier. Nor would general creep have removed such erratics. Wherever ledges at all heights up to twelve hundred feet and above the highest shore-line of postglacial submergence, were examined elsewhere in Labrador, glacial boulders were very plentiful. Thus, under essentially similar climatic conditions, the hills about Hebron have preserved their coating of glacial drift even on slopes much steeper than on these spurs of Mt. Ford. It was, therefore, a matter of no small moment to find, after prolonged search, an utter failure of erratic material on both spurs. Here, too, the bed-rock shows no trace of glacial smoothing.

At sixteen hundred feet, in the notch between Mount Elizabeth and Mount Ford, the Felsenmeer ceases in a steep talus-like slope. Below that level the valley-floor is composed of typical, well-polished and striated *roches moutonnées* covered with fresh subangular boulders, which, from their position, being often delicately poised on the tops of nubbles sloping outward on all sides, were evidently not brought thither from up the valley by waste-streams or snow-creep of present day dimensions. The erratic nature of these boulders of diorite and fine grained ferruginous schist resting on coarse hornblende gneiss, was clear in the field. The ledges, though often as steep as others occurring above the sixteen hundred-foot level, and though similarly devoid of vegetation, are yet hardly at all riven by the frost. The striæ and grooves are well developed and are invariably directed down the valley. At the cascade, "Korlortoâluk," they are confluent with grooves transverse to themselves and running seaward parallel to Nachvak Bay. Both sets of grooves agree with corresponding sets of lunoid furrows in indicating that the Nachvak trunk glacier flowed eastward and received at the cascade a south-flowing tributary. (Plate **12**.)

Thus, below sixteen hundred feet on the west and south slopes of Mt. Ford, there is a well glaciated zone. Above that level, steep slopes of streaming Felsenmeer have deeply covered the ledges. At twenty-one hundred feet and above, the ledges are in the utmost contrast with those lower down. This contrast is such as to enforce the belief that glacier ice did not reach higher than about twenty-one hundred feet above the present sealevel.

Similar evidence was found on Mt. Elizabeth, and the limit of glaciation was put at the same level as on Mt. Ford.

Although of no special importance in connection with the problem now under discussion, brief reference may be made to a curious novelty that was found in the search for the glacial limit on the twenty-five hundred-foot ridge east of the cascade, Korlortoâluk. About three-eighths of a mile from the waterfall at the measured altitude of sixteen hundred and twenty feet, there occurs a shallow col drained southward into the Bay and northward into the main hanging valley. This col is floored over completely with glacial boulders packed closely together so as to form two smoothly graded slopes gently declining in the directions of the drainage-lines mentioned. The total length of the doubly graded pavement is about two hundred and fifty yards. At either end it terminates in much steeper slopes of bed-rock. The width varies from thirty to fifty yards. The pavement is bounded laterally by glaciated ledges covered with erratics; the latter are plainly in a much fresher condition than the materials of the general Felsenmeer. That the deposit is not of the nature of a barrier-beach is clear from the subangular form of the boulders that show no sign of having been water-worn. There is, moreover, unequivocal proof that the land during postglacial time was not submerged more than about two hundred and fifty feet at Nachvak Bay. Similar doubly graded slopes of rock-fragments were discovered on Mt. Elizabeth at altitudes of twenty-two hundred and twenty-three hundred and fifty feet, but these seemed to be simply parts of the ordinary streaming Felsenmeer, as the rock-fragments were quite angular and deeply weathered. The two types may be analogous in origin, but it is difficult to imagine how an ice-sheet could veneer a col deeply and completely with typically ice-worn boulders. Without even a working hypothesis to go upon, the question of origin must here be left unanswered.

But the most satisfactory locality yet studied occurs in the Kogârsuk Valley. About two and a half miles from the delta of the brook and on the eastern slope of Kaputyat Mountain there is a series of ten lateral moraines at elevations of from seven hundred and fifty to seventeen hundred feet above sealevel (Fig. 3). The deposits are composed of large, relatively fresh, subangular boulders with a small intermixture of clay. The form of each moraine is that of a steeply scarped bench or of a distinct wall. One of the best defined ridges, at an elevation of twelve hundred feet, is from twenty to fifty feet high and some four hundred yards in length. The longitudinal and transverse profiles are in every way similar to those of a Swiss lateral moraine. Though generally arranged parallel to the valley-wall, in some instances the moraine is winged out from it and is then characterized by many shallow kettles and small ponds. The general slope of the moraine-crests is to the southward toward Nachvak Bay, and is sympathetic with the inclination of three well-marked rock-benches on the east side of the Kogârsuk Valley. Combining the evidence of groovings with these facts, it was evident that the glacier that was responsible for the moraines and benches flowed southward toward

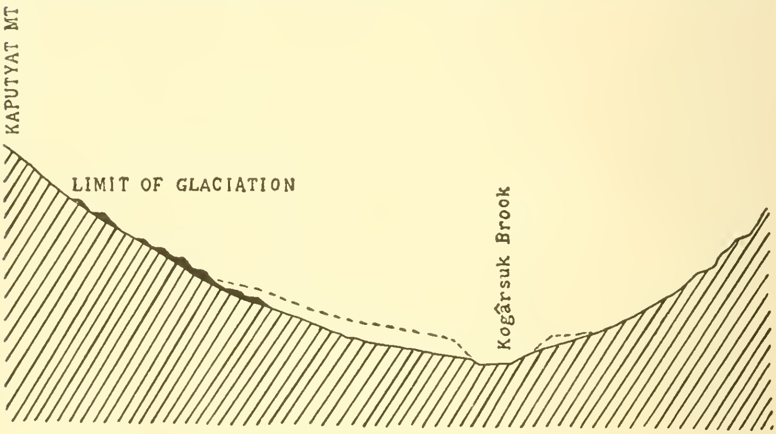

FIGURE 3. — Cross-section of the Kogârsuk Valley showing its bed-rock floor overlain by lateral moraines (solid black) and trenched ground moraine (dotted lines). Rock-benches on the right. Looking north.

the great fiord. At twelve hundred and fifty feet on the flat top of the long spur which lies in the angle between the fiord and the brook, a crescent-shaped frontal moraine nearly four hundred yards in length lies, as it were, stranded there, as the Kogârsuk glacier retreated to its narrower channel on the east.

The belt of lateral moraines, here and there broken down in the paths of entering side streams, extends five miles to the northward from its southern extremity. A little more than three miles from the mouth of the brook, the valley widens out in a notably flat stretch estimated to be at least eight miles in length and from one to three miles in width. The bed-rock is here deeply buried in a till-deposit which seems to be transitional into the terraced lateral moraines on the west much after the manner of similar deposits in the High Sierras.[1] It abuts directly against the bed-rock on the east where the lateral moraines are wanting. This great deposit, so unlike in composition and form any other considerable glacial product seen in northern Labrador, was interpreted in the field as a ground moraine. It is trenched to a depth of more than five hundred feet by the Kogârsuk, toward which the rough plain slopes on either side.

From seventeen hundred to nineteen hundred feet on Kaputyat mountain, fresh subangular erratics rest on the ledges. This zone is as recognizably glaciated as that of the morainal ridges below. But from nineteen hundred to two thousand and fifty feet there occurred an abrupt transition into the region of an interrupted, typical Felsenmeer in no way markedly different from that on Mt. Ford. The rock-fragments are sharp-angled, rusted to the deep brown color of the adjacent ledges and strikingly different from the gray tints of the fresher ledges and erratics below. The transition zone is represented, too, not only in the color, but also in the form, of the ledges. Though rapid, the change can be distinctly observed from well smoothed profiles to those which are extremely ragged. These various phases of transition would be expected if the glaciation of the valley had been purely local; its existence in no way obscures the essential contrast of the two limiting zones.

No erratics could be found above two thousand and fifty feet. Above and below the transition zone, the general declivity is constant in amount, and we cannot ascribe their absence above the zone to a more rapid rate of creeping. The residence of erratics on the tops of isolated spurs in the lowest zone forbids the idea that they could have crept thither from the higher zones.

The limit of glaciation in the Kogârsuk Valley is seen to be very nearly of the same altitude as on the flanks of Mt. Ford and Mt. Elizabeth, namely at twenty-one hundred feet above the sea.

Taking the Nachvak region as a sample of the whole of the higher Torngats, the general conclusion is that these mountains have not suffered, during the last advance of the ice-cap, even the limited amount of glacial erosion that may be discerned on the summits of Mt. Ktaadn, the Presidential range of New Hampshire, Ben Nevis and the neighboring peaked mountains of the western Scottish highlands, or the ragged outliers of the Scandinavian plateau. It is probable that the higher parts of the Kiglapait and the Kaumajet massifs similarly formed nunataks overlooking the late Pleistocene ice-sheet.

[1] I. C. Russell, U. S. Geol. Sur., 8th Ann. Rep., 1889, p. 360.

The Zone of Postglacial Emergence in Northeastern Labrador and in Newfoundland.

The path of the "Brave" was such as always to keep us in view of memorials of recent uplift of the land. These were found to be so numerous and so striking that one's note-books rapidly filled with the data of their nature and occurrence. If all other sources of geological interest failed on the coast, the singularly fresh records of emergence are yet sufficient to refute Lieber's statement that "the geology of Labrador is of extraordinarily little interest." The account of the cruise would be incomplete without reference being made to the observations made in connection with this subject.

Packard's summary in "The Labrador Coast" makes it unnecessary to review the earlier studies. Still more recently, Low has published the elevations of raised beaches in Ungava Bay, Hudson's Bay, James Bay, and in the interior of the peninsula.[1] So far as known, all the beaches described by both authors are of postglacial date and are related to the elevated shore-lines early described in the Gulf of St. Lawrence. On account, however, of the scant information we possess concerning the actual heights of the Atlantic coast beaches, no very definite correlation of these with one another or with the beaches farther west has yet been made. Thus an accurate idea of the amount or kind of elevatory movement that the Labrador peninsula has suffered in postglacial time, is yet lacking. What light last summer's coastal studies throw on the question will first engage our attention.

The barometric method was used in fixing elevations. Four standard compensated aneroids were employed. The accessibility of the sea-level and of the British Admiralty's triangulation stations as check-points, of course, give the aneroid an exceptionally large share of advantage as compared with that enjoyed by the same instrument working inland. It is believed that the error seldom exceeded five feet. At any rate, the accuracy obtained was sufficient for the main purposes of the study.

It was found to be impossible to group the beaches with reference to distinct levels, the deformation of which would indicate the type or types of crustal movement in postglacial time. At only one anchorage was there discovered a correspondence among the different beaches which showed that there were special beach-building periods in the whole time since uplift began. This was at Kirpon Harbor near Cape

[1] A. P. Low, Rep. Geol. Surv. Can. 1895, p. 308, and 1899, Part L.

Bauld, Newfoundland. Wave-built terraces were found at six, twenty-two, thirty-five, and seventy feet above high-water on the hills overlooking the harbor itself. Others measured six, twenty-two, thirty-five and one hundred and twenty feet in Mauve (Noddy) Bay. A third set on Kirpon Island measured six, twenty-two, thirty-five, seventy, and one hundred and twenty feet, and were particularly well exposed in Grand Galets Bay. The one hundred and twenty-foot beach-terraces match well with the very strong rock-benches on the headlands composed of the relatively soft slates about the entrance to Mauve Bay. At Grand Galets, where the indentation is deep both vertically and horizontally, terraces at all the levels may be seen. We hoped to find similar correspondences among the beaches across the Straits, but failed to do so. In Labrador nothing comparable to the beautiful system underlying the occurrence of the warped ancient shore-lines of the Great Lakes could be determined. It is impossible to deny that the uplift has been on the Labrador coast, as so often illustrated elsewhere, spasmodic, but it does not follow that this intermittent character will be reflected in the raised beaches of the present day. In most cases an ancient beach has been composed and located where it is because of special local conditions of formation and not because there occurred a halt in the uplifting process. Deposition takes place wherever the required protection against under-tow and shore-ice in the presence of appropriate off-shore depth, is afforded. (Plate 10.) If the hardness of the rocks, the off-shore depth, or the fetch and direction of the more effective waves were to change at a given point, the balance of conditions leading to beach-formation would be destroyed. Thus a beach growing under the former circumstances, might grow faster under the new; or, on the other hand, be demolished, its débris forming a new beach elsewhere or helping to raise the sea-floor whither it was dragged. Probably no single factor in producing such changes on the Labrador coast has been so important as vertical movements of the land.

Not only, thus, will those beaches that were really formed during halts in the elevatory process, be difficult to distinguish from those developed in protected bays as uplift takes place; the record of halts will be further masked by the appearance of beach-like deposits laid down on steep-to shores in several fathoms of water. An interesting example has been described by Packard as "a truly noble beach." It occurs on the south side of Sloop Harbor. It is about two hundred yards long and roughly graded from the one hundred and fifty-five-foot crest of the ridge enclosing the harbor on this side to the shore two hundred and fifty yards away. Most impressive was the view along the rugged accumulations of boulders, rounded or subangular and varying in diameter from six to ten feet. From the position of the "beach," it was clear that the enormous energy required to round off such boulders was derived from waves of great fetch and moving in water of some depth from the southward; that is, it looks as if the cyclopean Felsenmeer had been built up in the lee of the ridge at a time when the ridge was here entirely submerged. The heavy Atlantic breakers of that time rifted the masses from the bed-rock and threw them over the col into the protected place where we now see them.

When we also consider the fact that long stretches of the coast are too exposed to permit of the growth of beaches at all, it is clear that the discovery of general levels may be made only after several seasons of careful field-work. Even after such effort be expended, the quest may prove to be fruitless. The work that was done in this one summer certainly led to negative results.

Location of the Highest Elevated Shore-Line. — On the other hand, a considerable degree of success was attained in the attempt to fix the *highest* shore-line, *i. e.*, the most ancient of postglacial levels now warped into a form which is a resultant of all positive and negative movements of the land since uplift began. Along the eleven hundred miles of coast from St. John's to Cape Chidley, no trustworthy estimate had been made as to the position of this old level. The desirability of filling in this gap in our knowledge is evident. De Geer has attempted to construct a map of northeastern North America similar to his classic one of the Scandinavian Peninsula, showing the character of postglacial uplift.[1] His "isobases" join all points of equal uplift. The map was left incomplete, since, for lack of information, the isobasic curves could not be produced into eastern Labrador. Yet for the purposes of geological theory, it is of the highest importance that this edge of the glaciated tract should be similarly treated.

The principle used in the determination of the highest shore-line seems to have been in the minds of Packard and Hind during their early visits to the coast, but was applied by them only very locally. Shaler, and later Stone, used it on the coast of Maine, and it has been employed in Baffin's Land by Watson and Tarr, and still more extensively in Norway, Sweden, and Finland by De Geer and other Scandinavian geologists. The criterion is, in a word, that, on appropriate

[1] G. De Geer, Proc. Bost. Soc. Nat. Hist., 1892, vol. 25, p. 454.

headlands and hills where the surf from the open ocean can be felt on a glaciated shore during submergence, the present lower limit of undisturbed glacial erratics marks with but subordinate error the highest shore-line of postglacial submergence.

For the first time during the cruise, conclusive evidence of the value of the criterion on the Labrador shore was obtained at Ice Tickle Harbor. It is of importance to review the conditions under which it was there employed. These conditions are essentially the same as those found at the numerous other stations occupied up and down the coast.

The situation, topography, and bed-rock geology of the islands on either side of the tickle have already been described (p. 213). The dark-hued trap-ridges are dotted over with light gray gneissic boulders offering strong contrast in color and composition with the ledges beneath. These boulders are subangular, not water-worn, often greatly decomposed, and have evidently lain long in their present positions. They are associated with a small proportion of boulder-clay which is, in places, actively creeping down the slopes. Occasionally the boulders are perched and may be easily rocked with the hand. All these boulder-covered ridges are over 265 feet high. Those of less height are devoid of boulders; those of greater height may be divided into a boulder-covered and a boulderless zone separated from each other by the 265-foot contour. (Plate 8.)

That the boulders are truly glacial erratics, reposing practically where the great Labrador ice-sheet left them, can hardly be doubted. The only alternative origins which have suggested themselves are two in number. Either the boulders, originally deposited elsewhere by the land-ice, were thrown up by strong storm-waves, or they were brought thither by floe- or shore-ice. In spite of the unlikelihood of these hypotheses, it was held that evidence should be obtained that would thoroughly test them. The long ridge on the southern shore of Ice Tickle Island threw ample light on the question, and serves as an extremely good type locality for demonstrating the criterion.

This ridge, over a mile in length, and generally about three hundred feet in height (325 feet, measured barometrically at the highest point) is a residual hill situated where a thick trap dike projects above the softer gneisses. Its axial trend is roughly east and west. Its sides are very steep, running together at a sharp edge, whence one looks directly out over Hamilton Inlet on the south and over a deep valley and beyond over the open sea north of the island. There seemed to be no possibility that waves breaking on the ridge, submerged to the 300-foot, or any higher contour, could under normal conditions, transport large boulders from the adjacent depths and lodge them, delicately poised, on the summit of the ridge. The explanation by floating ice would leave out of account the great rarity of trap boulders, though these should be the commonest, since, during submergence, the only shoals for many miles around whence floating ice might derive rock-fragments other than glacial erratics, would be underlain by the trap of the present hills. Still less would the sudden cessation of this sort of deposition at the 265-foot level as the land arose, be explained. Finally, both hypotheses suffer from the difficulty that boulders, perched on the ridge-summit as we now see them, could not be left *in situ* if the rate of uplift were anything else than catastrophic. A single heavy storm from the southward would doubtless suffice to sweep all loose material from their precarious position. The conclusion that the boulder-covered zone has never been submerged since the general ice-sheet retreated from the country, cannot be escaped. On the other hand, the boulderless zone is a wave-swept zone.

Other evidences for former submergence of the lower zone are clear and convincing. The smooth, unbroken surfaces of the *roches moutonnées* above 265 feet contrast strongly with the jagged and riven ledges below that level. At the upper limit of the boulderless zone, low, but steep and rugged cliffs look northward over frequent pockets and graded slopes of well-rounded pebbles. Similar deposits were observed at 145, 155, and 175 feet, while an unusually fine boulder-beach fifty yards long and twenty in width occurs at 205 feet. The boulders, averaging six inches in diameter, are not covered with vegetation, and bear remarkable resemblance to the raised beaches of Hogland in the Gulf of Finland. Such beaches are rare on both Ice Tickle Island and on Rodney Mundy Island. That they were here not discovered more plentifully is due to the general steepness of the ridges and the consequent lack of places of lodgment for loose material; to the hardness of the rocks hereabouts, coupled with the shortness of the time allowed for beach-building; and to the abundance of moss and other peat-formers that develop thick vegetable mantles over most graded slopes. An indication of the great variety of form assumed by elevated sea-chasms, benches, and boulder-deposits in the wave-swept zone at other localities, will appear in the following pages.

Occasionally it was found that single boulders in exposed situations occurred below the accepted level of the highest shore-line. These were either too large to be moved by the waves, or had rolled down from the upper zone since emergence had taken place. Greater care had to be exercised with slopes covered with streaming drift. In such cases, masses of clay, small rock-fragments, and boulders compose small tongues or scalloped terraces, the forms assumed by these materials as they are washed each year farther and farther down the hill-side. Similar terraces were photographed in Alaska by members of the Harriman Expedition.

Between landing-places, a tolerably good idea of the altitude of the highest shore-line could sometimes be attained. The treeless nature of the headlands caused the boulders of the upper zone to stand out with great clearness in the different profiles of the hills. As our schooner hugged the shore pretty closely on the northward, or "downward" journey, the line could often be located within an error of ten or twenty feet. If by good fortune, the cairn of a triangulation station were also in the view, it was often possible to secure quite useful information concerning the line. A difficulty in using the cairns was, however, found along the northern half of the coast. Not only are the charts of that section very incomplete and inaccurate; it was often not possible to distinguish the Admiralty cairns from those erected in great numbers by the Eskimo on prominent hills, — the "American men" of the fishermen.

Finally, it is worth noting that the boulder-limit does not exactly represent the actual former level of the sea, which will be a few feet below the limit. The ancient waves would have an effective reach for some distance above high-water mark.

Table III. summarizes the results of the observations on the highest shore-line. At most of the landing-places the land was high enough to show the line. At others, all the hills ascended were found to be clean swept. (Plate 8.) For each of the latter the elevation of the highest hill is given in the table. There also appear the estimated heights of the line determined from the schooner on islands and headlands surmounted by triangulation cairns. The table shows that the uplift on the Labrador coast has been greatest near Hopedale. Hamilton Inlet owes in part its depth, and, indeed, its very existence as an inlet (it is but 10 fathoms deep at the Narrows), to the fact that the part of the plateau on which it lies has not been elevated as much as the land to north and to south. The line rapidly rises as it crosses the Strait of Belle Isle, and seems to be about 500 feet in height along the whole eastern shore of Newfoundland. It was last observed at St. John's. Signal Hill (508 feet) is clean swept. The ridge on the south side of the Narrows is boulder-covered and the line was estimated at the dis-

TABLE III.

Observed Heights of the Highest Postglacial Shore-Line in Newfoundland and Labrador.

Note. — Numbers enclosed in brackets refer to altitudes estimated at a distance by the use of the boulder limit and the triangulated points of the Admiralty charts. Numbers followed by the plus sign give the heights of clean-swept hills too low to show the highest shore-line.

Locality.	Average Altitude obtained for highest Shore-Line, in Feet.	Altitudes of Beaches in the Wave-swept Zone.
St. John's, Newfoundland .	508 + [575]	washed gravels at ca. 400 feet on Signal Hill
Cape Rouge Harbor, Newfoundland	505	
Kirpon Itland, Newfoundland	450 +	beaches at 6, 22, 35, 70, 120 feet
St. Francis Harbor . . .	365	rolled boulders at 260 feet
Venison Tickle	[325–340]	
Near Domino Harbor . .	[ca. 300]	
Gready	[260]	
Ice Tickle	265	washed gravels at 145, 155, 175, 250, 255 feet; beaches at 140, 205 feet
Sloop Harbor	265	beaches at 115, 140, 160, 215 feet
Mainland N. W. of Conical Island	290 +	
Pomiadluk Point	345	gravels and beaches at 55, 65, 245, 250, 255, 260, 275, 315, 320, 335 feet
Cape Strawberry . . .	[350]	
Aillik Bay	355	beaches (many below 100 feet); rolled boulders at 255 feet
Hopedale	390	beaches at 125, 270, 370, 385 feet
Quirk Tickle, 25 miles S. of Ford Harbor . . .	340	rolled boulders at 250 feet; beaches at various levels
Ford Harbor	290	beaches at 145, 200, 245 feet; many at lower levels
Black Island Harbor (Newark Island) . . .	290	several barrier-beaches at 50 feet
Port Manvers	285	beaches and bars at 210 feet and lower
Cutthroat Tickle, 25 miles N. of Port Manvers . .	270	
Mugford Tickle	265	
Hebron	260	several beaches up to 225 feet
Kipsimarvik, Nachvak Bay	250	many small pockets of beach-gravels up to 185 feet

tance of the width of the Narrows, to lie at the 575-foot contour. No opportunity presented itself for the ascent of this southern ridge; hence the line at St. John's could not be placed more accurately.

The observations at the Hudson's Bay Post in Nachvak Bay gave as indisputable evidence of the relatively low position of the highest shore-line as was obtained at the other coast stations. The position of the boulder-limit and the entire absence of elevated beaches at heights greater than 250 feet mean that that elevation is very close to the level of greatest postglacial submergence.

If the record of the table be put in graphic form (Figure 4) it becomes still more evident that along the eleven hundred miles of coast the elevation has been differential. The pronounced warping of the highest shore line is incompatible with the view that changes in the position of the level of the sea over great stretches of the earth's surface, are produced solely by independent vertical movements of the surface of the ocean.

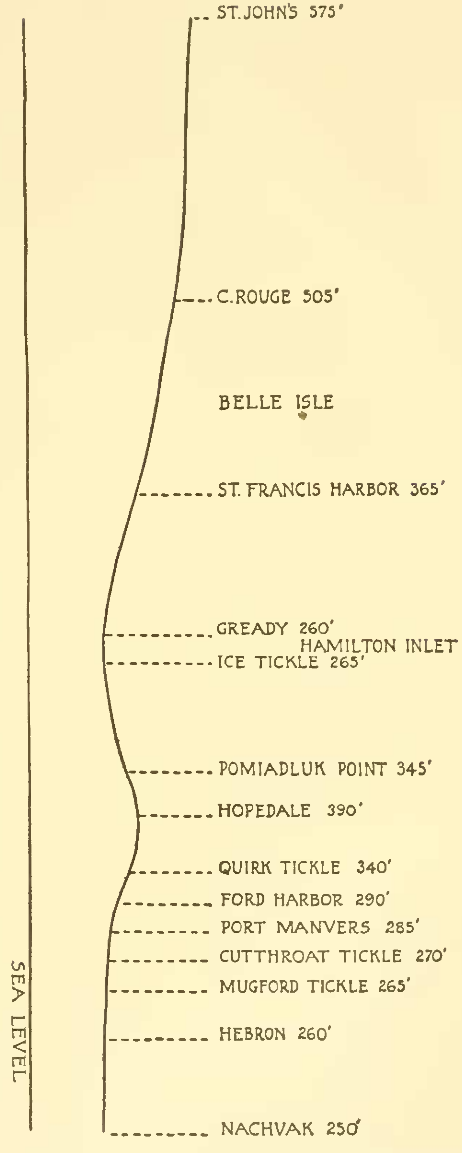

FIGURE 4. — Curve showing the present warped condition of the highest postglacial shore-line between St. John's and Nachvak Bay.

Along the line on which our observations were made, there has been unequal positive uplift of the earth's crust. The force responsible for this great piece of work has been applied locally and in varying degree. The result is that to-day the actual distance from the centre of the earth of every point on that line is greater than it was at the close of the glacial period.

The coastal belt shows a degree of elevation considerably less than that demonstrated for the region east and southeast of James Bay. Supplementing the data of Low's and De Geer's maps with the writer's observations on the northeastern coast, one is led to the conclusion that the uplift of the glaciated tract of this part of America has been greatest near the region of the central névé.[1] The result is to strengthen De Geer's parallel between the postglacial behavior of the earth's crust in northeastern North America and in northwestern Europe. The bearing of this conclusion on the theory of isostasy is obvious. Perhaps the relatively great uplift of Newfoundland is connected with the local character of its glaciation, which, according to Chamberlain, was not due to an extension of the ice-fields of the mainland.[2]

Boulder Barricades. — There is not wanting an indication that on the Labrador coast, at least, the land is higher to-day than in any other part of postglacial time. Wherever the shore slopes are not too steep, the coast is belted with lines of innumerable large boulders visible between low and half tides. These accumulations may be called "barricades." The name is recognized as appropriate by any one who attempts to land at low water by forcing a small boat through a gap in the nearly submerged wall of boulders. The barricade is situated twenty to one hundred or more feet from the shore according to the slope of the foreshore; the distance is greater as the slope is the more gentle. Plate **9** gives a typical view of one seen at Ford Harbor. Lyell long since figured an example in the "Principles of Geology (ed. 11, 1892, Vol. I. p. 381).

Of particular significance is the fact that, in practically every case where one of these accumulations was examined, it proved to be composed essentially of large glacial erratics. These are believed, in most cases, to have been derived from the wave-swept zone immediately above. As the land emerged, the boulders were dragged down in the undertow and lodged just below the level where the surf could move them. The relative absence of boulders between the shore and the barricade is also explained in part by the action of coast-ice, which floats off such boulders when the ice-foot breaks up. If the boulders happened to be

[1] Proc. Bost. Soc. Nat. Hist., 1892, vol. 25, p. 464.

[2] Bull. Geol. Soc. Amer., 1894, vol. 6, p. 467.

dropped again just at the limit where, on account of the depth, the surf is no longer effective in moving boulders resting on the bottom, the erratics would further build up the wall constructed by the undertow. Very close to that limit of effective wave-wash, the winter-ice, because of the depth at which the boulders lie (submerged at high tide), would not be able to buoy up the heavy masses and float them away.

If the land had, in postglacial time, ever been higher than to-day, erratics won from the wave-swept zone would have moved seaward beyond their present position through the operation of the causes just described. During a subsequent uplift of the land, the boulders could not, in any large number, be recalled to the new shore-line. The actual magnitude of the average barricade is certainly too great to warrant the belief that the waves would, under this condition, undo what they had, during the progress of elevation, accomplished. The character of the material making up the barricade and its organic relation to the wave-swept zone forbid, thus, the assumption of a secondary uplift following a former greater postglacial depression of the land than we now see.

One is forced to reject the idea that the barricades have been principally formed by 'longshore transport of boulders. The walls are developed very uniformly at the mouth and head, and along the sides of long bays. If they were the result of 'longshore deposition by floating ice, we should expect the accumulation of dropped boulders to be quite uneven, most pronounced where floes and pans most frequently strand, and, at other points, scarcely begun. It cannot be denied that coast-ice does carry boulders in this way, but one may justly question its ability to have performed so great an amount of work as that demanded in the construction of the barricades. For this hypothesis implies that the sea-floor along the broad track of the annual field-ice is peppered over with glacial erratics far greater in number than could have been furnished by the wave-swept zone, if that zone had had anything like the average proportion of the drift now seen above the highest shore-line.

Continuance of Elevation. — We cannot doubt that the elevatory process continues in both Labrador and Newfoundland. The almost universal belief of the old settlers on these shores is that in no other way can the changes in depth at familiar localities be explained. With no theory to support or refute, many reputable observers among the fishing population state that they have time and again noted, during periods of from thirty to sixty years, cases where rock-ledges have come perceptibly nearer the sea-surface, where new channels have had to be sought among the shoals for the passage of their fishing-boats, and where the stages must be again and again lengthened over their bed-rock foundations in order to secure a depth of water sufficient to float the small craft. Mr. Mark Gibbons, of St. John's, has made a study of the question for forty years, and has come to the conclusion that elevation is in progress along the whole coast. He believes that the rate of uplift is about twice as rapid in northern Labrador as in Newfoundland. He has found among the older settlements of the island some where the inhabitants are in a very unfavorable position for plying their industry on account of the rim of just submerged rock-ledges that obstruct the harbors. He has asked the older men why they chose such locations for settlement. The reply was that they or their fathers had made these harbors when the conditions were very different from the present, namely when the harbors were deeper. Such qualitative evidence, however great in amount, must yield in value to the testimony of even a few bench-marks carefully distributed along the coast. It is hoped that, with the co-operation of Bishop Marten of the Moravian church, of the missionaries under his charge at the various stations, of Dr. Grenfell and of Mr. Ford at Nachvak, a description may be published during the coming year of eight bench-marks fixed by these gentlemen. One of the stations is planned for northern Newfoundland.

The Scenery of the Emerged Zone. — The coastal landscapes exhibit many details which are those expected after the sea-bottom has been exposed by elevation. They figure among the most striking proofs of crustal movement.

Within the labyrinth of islands, wave-cutting has done little toward modifying the condition of the glaciated ledges. Outlying islands and headlands, as, for example, at Sloop (Brig) Harbor, Hopedale, Cape Harrison and Cape Strawberry, are usually very ragged and wave-worn throughout the wave-swept zone. The same contrast holds in the case of many individual islands which are uninjured on the landward side but strongly fretted on the seaward face. On the wooded hills of Great Bréhat and Cape Rouge in Newfoundland, where the slates and other sediments present relatively small resistance to sea-attack, the highest shore-line was the more easily determined because of the dissimilarity of the ragged zone of emergence and the smoother, erratic-covered zone. Benches and strong wave-cut cliffs, at all elevations up to the level of the highest shore-line, appear at almost every exposed point on the Labrador. An exceedingly picturesque sea-cliff occurs just above a 205-foot beach on Pomiadluk Point. Others were particularly noted on Cape Harrison, Cape Strawberry, at Sloop Harbor, at Ice Tickle, and at Aillik Bay.

Very rarely are the benches of great breadth or length; nor are they usually horizontal. They have been developed by rifting on gently curving master-joints. They are not the continuous, horizontal terraces of our text-book diagrams. The benches cannot be taken to mean so many halts during the process of elevation; but are rather determined in size, form, and position by the controlling planes of jointing.

Elevated sea-chasms, often located on trap-dikes, indent the cliffs in large numbers. The great length of some of these is quite extraordinary. A half mile northwest of the Mission House at Hopedale and at an altitude of 325 feet, a chasm three hundred yards in length has been worn out during submergence by waves that followed the trend of a trap dike. The vast majority of the fossil chasms are similarly located on trap dikes. The latter, with respect to subaerial destruction, may be hard in comparison to the country-rock and project above the highest shoreline as ridges; below that line the same dikes may prove less resistant to the attack of the waves than the country-rock and have thus served to locate chasms. Examples occur on the shores of Aillik Bay. The position of the highest shore-line is beautifully shown at the upper termination of a dike-chasm, still floored with rounded boulders, that forms a conspicuous landmark above the anchorage at Ford Harbor. Above the line, the surface of the dike is flush with the glaciated gneiss. The most picturesque chasm seen during the summer is one 250 yards long, 75 feet deep, and 20 feet wide that was found on Long Island, at American Tickle. The waves still reach nearly to the head of this chasm, which is still being slowly deepened.

The waste of the fossil cliffs is seen at the present day in the raised beaches and other boulder accumulations that also represent, in part, the rearranged drift that once lay scattered over the emerged zone. In Newfoundland and southern Labrador, these deposits are as a rule covered deeply under peat, which seems to prefer such graded slopes as a place for rapid growth. The form and location of the slope was, in such cases, used in connection with the natural sections of brook-beds to indicate the nature of the deposit. North of Hamilton Inlet, the lack of a vegetable cap has rendered the exposures extremely good and the study easy and rapid. (Plate **10**, a and b.) Perhaps the finest exhibitions of the beaches were seen at Sloop Harbor (altitudes measured 115, 140, 160, and 215 feet), Aillik Bay, Hopedale, Pomiadluk Point (at 55, 65, 230, 250, 260, 315, 320, and 335 feet), and Port Manvers.

The development of the beaches was naturally found to be a function of four conditions, the relative amount of drift on the shore, the amount of resistance offered by the bed-rock to wave-erosion, the degree of protection afforded by outlying islands or shoals against the ocean-swell, and lastly, the height of the beach above the sea.

Near Cape Porcupine and north and south of Paul's Island, two typical regions are seen where the drift seems to have been left by the ice-sheet in much greater amount than elsewhere on the coast. Consequently, the "beach" of other parts becomes a coastal plain at the Cape, or a huge sand and gravel spit in the lee of many an island near Ford Harbor.

In Labrador, the fossil shore-lines have repeated the process exemplified on the existing shore of eastern Newfoundland. The porphyritic granite of Greenspond is suffering but very slow attack by the waves, and the coast is there for many miles devoid of beaches. Approaching Change Island from the south, one is struck by the more advanced development of the shore-line as illustrated in the abundant pocket-beaches and barrier-beaches wrought out of the fissile slates, quartzites, and schists.

Lying well within the island-belt, the hills about Rogue's Roost, Quirk Tickle and Cutthroat Tickle possess comparatively few beaches. In the time of submergence, the outer islands bore the brunt of erosion by the waves; the enfeebled Atlantic waves were unable to damage seriously the bed-rock so that it should furnish an essential part of the beach material. Where beaches do occur in this situation, they are almost entirely composed of glacial erratics, — a constitution that goes far to explain the usual contrast of the higher and lower beaches. The latter are the better developed both as to size and to the degree of rounding which the erratics have suffered through wave wear. This contrast is natural, for the lower deposits are mainly made up of boulders and pebbles that have been derived from the upper part of the emerged zone, and thus have been longer in the mill of the surf than the materials earlier lodged farther up the slope. At the same time, the loss of bulk by attrition has not been sufficient to counterbalance the gain to the lower beaches produced by the winning of erratics from above.

On some of the sand beaches, dunes apparently fossil and dating from a lower stand of the land, were discovered at varying heights above the sea. These are especially large and numerous in West Bay just south of Hamilton Inlet. At Pottle's Cove (West Bay) a fifteen-foot pocket beach two hundred yards long has resting upon it a number of typical dunes; the top of one of these is forty-five feet above high water mark. A much larger area of dunes fifteen to twenty feet high, covers an extensive thirty-five-foot terrace on the south side of West Bay. The antiquity of the dunes is indicated by the thick vegetable cap that has long kept them stationary and in essentially their present form.

The settlements on the Labrador are largely confined to the graded terraces close to sealevel. Their accessibility, relatively smooth surface, and naturally sheltered positions, have determined the location of houses, fishing-stages, and the long lines of bawns on which the codfish are dried. The inevitable graveyard is always situated on a raised beach, for only there is there sufficient depth of loose material on the bed-rock.

True pocket-beaches could not be sharply separated from boulder and pebble deposits that have been formed on steep-to shores or in the lee of submerged rock-knobs in several fathoms of water. With the latter are associated the very common aggregations of boulders flooring the little rock-basins situated among the mammillated ledges of the emerged zone. In this record therefore, the term "beach" may, in certain instances, be arbitrarily used.

One of the commonest forms assumed by the shore-detritus, is that of the barrier-beach or of its relative, the tombolo or tying-on bar. Fine examples of these occur at Port Manvers and at the eastern extremity of Paul's Island. The settlers on the coast recognize that certain peninsulas have been formed by the tying on of rocky islands to the mainland ; such islands of an earlier time are locally called "barred islands." The recency of the shore-uplift is well shown in the numerous fresh-water ponds lying back of raised barrier beaches. Their basins represent either true coastal lagoons or the depressions located on the landward side of submarine bars. Often a series of bars form, with the tied-on rock-islands, the rim of a pond. Examples can be found at Mauve Bay, Newfoundland, at Pottle's Cove, West Bay, at Ford Harbor, and at Black Island Harbor. In every case, the pond exhibits extremely little infilling with wash from the adjacent hills, nor has the growth of peat significantly diminished the size of the basin. The freshness of form corroborates in striking degree the other evidence that goes to show how lately the land has emerged from beneath the sea. Occasionally the bar is cut through by a stream that has thus destroyed the integrity of the basin lying back of the bar.

Not the least conspicuous features of the views obtained along the coast, are the fossil spits such as those at Jigger Island, Sandy Island, Ford Harbor, John's Harbor and in the vicinity of Nain. Tailing off with beautifully even slopes from a few hundred feet to more than a mile in length, the spits invariably lie on the lee side of the islands to which they are attached. In most cases they appear to be still growing on their points although the flanks may be strongly cliffed by the waves; sometimes a spit will form a continuous bar from one rock-island to another.

Finally, attention should be called to the largest single deposit occurring in the zone of emergence and the only relatively large example of its class of geographic form on this coast: the coastal plain north of Cape Porcupine. From the cape it stretches fifteen miles northwestward to Tub Harbor at the North of Hamilton Inlet. The plain averages nearly four miles in breadth. It is covered with a thick growth of scrub timber which does not conceal its well graded character. The upper limit of the plain surface was estimated from a distance to be about two hundred and fifty feet above the sea; thence the smooth slope descends to the straight cliffs now being driven back by the actively encroaching sea. The plain has apparently lost rather more than a mile of its breadth in this way. There was a comparatively long halt in the process of elevation when the sealevel was about thirty-five feet above its present position; at that time there was developed a distinct bench that is visible in West Bay. The plain is underlain by stratified sands, and clays in which there are embedded a great number of large boulders, including anorthosite from the interior. The bulk of these materials may doubtless be referred to the drift as their original source. Many small consequent streams have been extended down the slope of the plain and are now deeply entrenched beneath its surface. The finest sand-beach on the Labrador sweeps in a great curve along the present shore.

The clays of the coastal plain seemed to promise that in them, if anywhere on the coast, fossiliferous beds might be discovered; but, even after prolonged search, the hope was destined to disappointment. Nor was better success to be had when other deposits of the coast were examined. It may be that organic remains are truly rare in them, but the short time permitted for the investigation of the beaches could not at all warrant this as the final conclusion. The rich finds of Packard at Hopedale and on the coast to the southward, certainly point to the expectation that the Labrador Quaternary may some day afford data sufficient for a fruitful comparison with beds of the same age all about the north Atlantic.

The Need of Further Exploration.

One cannot leave the consideration of this huge field of research, the northeast coast of Labrador, without indicating some of the directions in which repaying investigation might be carried on. Packard said in 1891 that "the Labrador Peninsula is less known than the interior of Africa or the wastes of Siberia."[1] Since that time a harvest of new facts has been reaped by Low in connection with the Canadian Geological Survey, and the secrets have to some extent been told. Packard has himself done much to remove this stain on the banner of American geological and geographical enterprise, in the publication of his book, embodying as it does many original observations. Yet, in his account of the coast, he was forced to sketch in but the briefest fashion, that part of it which is by long odds the most interesting, the region north of Hopedale. It is probable that for many years it will be impossible for government surveyors to be called away from economically more important fields to make thorough exploration of the coast. That work seems marked out by nature for private ventures.

Escaping from the heat of an American or Canadian summer, the explorer of northern Labrador will find a bracing, health-giving climate calling forth strenuous and welcome exercise of body and mind. If he be particularly interested in geological structures and processes, he will find, in the lack of soil and forest-cover, most fortunate conditions for rapid observation. Using a steamer sheathed for ice-navigation, an exploring party might be on the ground in early July and, from one end of the coast to the other, rarely fail to find a snug harbor close to the important points of attack.

The Kiglapait is unmeasured, unmapped and absolutely unknown as to composition. The Kaumajet sediments, covering several hundreds of square miles, present important structural and stratigraphic problems. Their age is quite undetermined, like that of the stratified rocks at Aillik Bay, at Pomiadluk Point and at Ramah. The Torngats afford a field of operations which it will take many seasons even to reconnoitre. In the last mentioned range are the highest mountains on the Atlantic seaboard of America, unmeasured and almost entirely unnamed. It would be of much importance to fix the elevation of the highest postglacial shore-line in the interior of the peninsula as well as on the south coast, in Newfoundland, Cape Breton and across Hudson's Strait, where isolated

[1] The Labrador Coast, Preface, p. 5.

observations have already been made. The gross imperfection of the government charts for the region north of Cape Harrigan is such that no just idea is given of the splendid fiords that indent the plateau. These should be sounded and mapped if the great fishing fleet is to find appreciable help in their arduous calling from those who can afford the leisure to do this necessary work. The Labrador should be mapped at least as carefully as the coast of northern Norway. With the mapping, detailed observations of value on the hydrography of the coastal waters could be carried on. The remarkable tides of Ungava Bay, the marine zoölogy of the coast, particularly the study of the jelly-fishes, the fixing of bench marks to show the rate of elevation on the coast, the study of the fossiliferous beds of the raised beaches, — these and other subjects of research await the explorers of the future.

EXPLANATION OF PLATES.

PLATE 1.

The basalts and underlying sediments of the Mugford Series as exposed on the northwest side of Mugford Tickle. The basement of crystalline rocks is seen on the left. It disappears near the middle of the view in consequence of the strong flexure revealed in the attitude of the stratified rocks above. The cliff is about 1,800 feet in height where it rises above the exposed basement.

PLATE 2.

The unconformity of the Mugford Series and Crystalline Complex, at Cape Mugford; cliff here from 1,800 to 2,000 feet in altitude.

PLATE 3.

The Tallek, or southern arm of Nachvak Bay; view taken from the height of about 1,500 feet on the southern slope of Mt. Elizabeth. Mt. Idyutak on the left.

PLATE 4.

The highest cliff in the Tallek; the cloud-capped peak on the left is the summit of Mt. Idyutak, 3,400 feet in height; view taken at a distance of about one mile from the shore.

PLATE 5.

Glacial amphitheatre near Mt. Razorback, north of entrance to Nachvak Bay; looking north.

PLATE 6.

Hanging Valley of the Korlortoâluk, Nachvak Bay (see Plate 12); Mt. Elizabeth on the left, separated from Mt. Ford on the right by a glaciated col; this col is drained into the main hanging valley, which comes in from the right; looking north.

PLATE 7.

Glacial lunoid furrow, one foot from horn to horn, and an inch and a quarter in depth; found with many others on hornblende granite at Hopedale.

PLATE 8.

Wave-swept zone as represented in Bear Island, a granite knob cut by trap dikes; about 100 feet in height.

PLATE 9.

Boulder barricade at Ford Harbor; at half tide; looking east.

PLATE 10.

a. Elevated gravel beach and sand dune at West Bay, south side of entrance to Hamilton Inlet; beach 35 feet above high water.
b. Near view of boulder beach 100 feet above high water; west (lee) side of Brig Harbor Island.

PLATE 11.

Sketch map of the northeast coast of Labrador, showing data concerning bed-rock geology. Heavy straight lines: observed strikes. Sinuous lines: average strike of contorted schists. Horizontal lining: Ramah series. Vertical lining: Mugford series. Solid black: Nain gabbros.

PLATE 12.

Sketch map of Nachvak Bay. Heights in feet; depths in fathoms.

PLATE 13.

Sketch map of Newfoundland and part of the Labrador peninsula, showing data concerning glacial geology and postglacial elevation. Arrows indicate observed directions of glacial striae; numbers show local elevations of highest postglacial shore-line about present high water. (See Table III.)